

Foraminifera of the Togopi Formation, eastern Sabah, Malaysia

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Synopsis

One hundred and twenty-five species are described and figured from a section in the upper Togopi River, type-locality of the Togopi Formation, eastern Sabah, Malaysia. Eighty-six per cent of the fauna is living today in the area. The following seven species and one variety are new: *Ammonia togopiensis*, *Bolivina sabahensis*, *Cellanthus biperforatus*, *C. hailei*, *Criboelphidium dentense*, *Peneroplis planatus* var. *annulata*, *Pseudomassilina medioelata* and *Textilina subrectangularis*. *Florilus asanoi* is proposed as a new name for *Nonion japonicum* Asano, 1938.

The age of the Togopi Formation is reassessed on the basis of benthic foraminifera and is considered to be mainly of Pliocene age.

Introduction

The Togopi Formation, the uppermost sequence of mainly marine clays making up the Dent Group, is named after the Togopi River, eastern Sabah, Malaysia. The name was first published by Reinhard & Wenk (1951) but it had previously been used in a Sabah Shell Petroleum Company's (SSPC) internal report as early as 1938. Dr E. Wenk himself made the first collection of fossils (Mollusca) in 1937, some of which were described by Cox (1948). A further collection of macro-fossils was made by P. Collette in 1950, the Mollusca being listed by Nuttall (1960). Cox dated Wenk's material, which was dominated by gastropods, as Pliocene or possibly U. Miocene, while Nuttall considered Collette's samples to be almost certainly Pleistocene. The former collection came from the Togopi River, but there is some confusion as to the exact provenance of Collette's (Nuttall 1965).

In 1961 Dr N. S. Haile collected 18 samples from the type area for the Togopi Formation from its supposed boundary with the underlying Ganduman Formation to where it disappears under the coastal alluvia (for details see Haile & Wong 1965). From these Nuttall (1965) listed almost 200 species of Mollusca and after a detailed examination of the fauna assigned a Plio-Pleistocene age, equivalent to the Bantamian-Sondian stages of Java, to the Togopi Formation. Haile & Wong (1965: 83) list identifications of teleostan otoliths by F. Stinton (Stinton 1963) and echinoderms by R. P. S. Jefferies together with a small foraminiferal fauna, identified by SSPC palaeontologists. The foraminifera came from samples collected by Wenk and Parsons between 4 and 13 km west and north-west of Dent Haven, but only a few genera and species were recognized.

Eleven of Haile's original samples were available for micropalaeontological examination, and in view of the richness of the fauna (125 species) it was decided to describe it fully and to attempt an age determination using the smaller benthic foraminifera. Planktonic foraminifera are unfortunately few in the Togopi Formation. Since 86% of the fauna still lives in the Indo-Pacific today it has also been possible to correct some common misidentifications of Recent species by referring back to the original collections of Brady, Parker & Jones, Carpenter, Williamson and Heron-Allen & Earland which are preserved in the BM(NH). A number of benthic species are now thought to be extinct and these are listed as of possible biostratigraphic use in the future.

Four samples from the small Wenk and Collette collections have been examined for foraminifera but yielded no additional species. They are not dealt with any further in this paper.

The stratigraphy of the Dent Group is first discussed. The ages of the Sebahat and Ganduman Formations given by Haile & Wong (1965) are revised and the foraminiferal faunas reinterpreted in the light of recent advances in Tertiary biostratigraphy. A description of the Togopi stratigraphy and the material from the type-area which forms the basis of this work is then covered

in detail. The occurrence of the foraminifera is summarized, their palaeoecology considered, and finally the overall evidence of the age of the Togopi Formation is presented.

The planktonic foraminifera have been identified and photographed by Mr H. A. Buckley, Department of Mineralogy, British Museum (Natural History).

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We are indebted to our colleague Dr C. G. Adams for his encouragement and guidance in the preparation of this work and for his careful reading of the manuscript. To Dr D. J. Belford (Bureau of Mineral Resources, Canberra) goes our thanks for valuable discussions and for comparing a number of our species with his own from the Neogene of Papua-New Guinea; Dr R. W. Ponder (James Cook University, Townsville) also contributed a lively correspondence on several problematic species. Dr P. Marshall (formerly of University College, London) provided us with topotypic material of some of d'Orbigny's Caribbean species, while Dr H. Billman (formerly of the Union Oil Company) is also thanked for his kindness in making available to us examples of index and important marker fossils from the Kutei Basin, Indonesia. Dr R. Cifelli (Smithsonian Institution) readily arranged several loans of type-specimens. Dr J. R. Haynes (University College of Wales, Aberystwyth) gave us many helpful suggestions on taxonomic matters, while our colleague Mr C. P. Nuttall provided valuable information on the Togopi samples and their molluscan faunas.

The photography was undertaken by the senior author and by members of the Department of Central Services, British Museum (Natural History); to the latter we are especially indebted for their careful work. Some technical assistance was provided by Miss C. A. Harrison and, in the early stages, by Mr D. I. Dixon, formerly of the Museum's staff. Mrs E. M. Richards typed the manuscript.

Methods

The dry clay samples were disaggregated by boiling in a weak solution of hydrogen peroxide. The sediment was then washed through a series of sieves, the finest being 200 mesh (aperture: 75 microns), and dried. The original weight of the samples is not known, having first been examined for mollusca; however, the amount of material processed in the present study varied between 200 and 700 gm, five of the samples weighing approximately 400 gm. In order to speed up the examination process, the residue, obviously variable depending on the size of the clay fraction, was halved or quartered, and half (or a quarter) subjected to carbon tetrachloride flotation. Where the residue was large the flotation process was repeated and in the coarsest grade, when large specimens were present, bromoform was used. As no statistical study was to be attempted, only the floated portion and its residue were examined.

The friable limestones (NB 9446, NB 9448) and part of the sandstone (NB 9453) were either crushed and washed, or sectioned.

Internal structures of the foraminifera were examined: (a) by vertical, horizontal and oblique thin- and block-sectioning using a 'Lakeside 70' cement mount; (b) by immersion in various clearing fluids (usually clove oil); (c) by solution with a weak hydrochloric acid and 'Cellofas' 'mush', the specimen first being mounted in 'Lakeside'; and (d) by 'heat splitting' to produce half-sections of the Nummulitidae.

Most of the species have been illustrated using a Cambridge Mk II 'Stereoscan' scanning electron microscope, the micrographs having been taken mainly by one of the authors (J. E. W.). The specimens to be photographed were first cleaned with a 25% solution of the enzyme cleaning agent 'Decon' and placed on aluminium stubs. A variety of stub mounting techniques were used. In some cases a glass cover-slip was cemented on to the stub using silver 'dag' and the foraminifera were then mounted on the glass using 'Cellofas'; in other cases the specimens were directly mounted on the stub using 'Kodafat' adhesive. A third technique, of mounting on a piece of negative film which had previously been cemented to the stub with 'Durafix', also proved satisfactory; the gelatine of the film when wetted provides enough adhesive to anchor the smaller

foraminifera sufficiently. The specimens were then coated with several layers of gold before scanning and photography.

Part of Pl. 8, the whole of Pl. 9 and the thin sections of Pl. 10 were photographed with a Watson 'Holophot' Photomicroscope by the Museum's photographic unit.

The text-figures were mainly drawn by one of us (R. L. H.) with the aid of a light microscope and camera lucida attachment. The measurements of *Operculina*/*Nummulites* were taken from tracings of the embryonic apparatus on the Projectina (Model 4014) microscope.

Biostratigraphy

Stratigraphy of the Dent Group

The Dent Group of the eastern Dent Peninsula, Sabah, comprises, in ascending order, the Sebahat, Ganduman and Togopi Formations. A thick (c. 14 000 ft or 4300 m) mainly marine sequence of predominantly clastic sediments with subordinate limestones, it locally overlies the Miocene Segama Group unconformably. The Togopi Formation is itself overlain with slight unconformity by about 100 ft (30 m) of Quaternary terrace and Recent river alluvium (Figs 1, 2). The main structural feature is a broad anticlinal uplift trending ENE down the centre of the peninsula, off which the three formations dip gently in a more or less conformable sequence.

Sebahat Formation. This is estimated by Haile & Wong (1965 : 74) to be over 7500 ft (2290 m) thick and was laid down in the sublittoral and neritic zones of the Neogene sea. They also state (1965 : 75) that it contains abundant foraminifera which have been identified by SSPC micropalaeontologists; these include rich planktonic faunas, larger foraminifera and small benthics, none of which has ever been described or illustrated. This Formation was dated as 'late Tf (late Miocene) to early Tg (early Pliocene)' by Haile & Wong. *Globigerinoides obliquus* Bolli is said to characterize the greater part of the unit. This, according to Postuma (1971), ranges up to Zone N18 (Upper Miocene/Pliocene boundary), but Blow (1969) would extend the range as far as Zone N22 (Pleistocene). In the lower part of the Formation several good age indicators are however present: *Globorotalia mayeri* Cushman & Ellis, *Globigerinoides subquadratus* Brönnimann, *Globorotalia praemenardii* Cushman & Stainforth and *G. fohsi* forma *robusta* Bolli. Their joint occurrence suggests an age not older than Zone N12 or younger than the early part of Zone N13 (M. Miocene). The Tabin Limestone Member (middle Sebahat Formation) is said by Haile & Wong to contain *Cycloclypeus* (*Katacycloclypeus*), a larger foraminifer believed to be restricted to Lower Tf (M. Miocene) (*vide* Adams 1970). This identification has recently been confirmed by Dr Adams (personal communication), who has examined four samples of limestone from a 30 ft (9 m) bed west of the Tabin River. Apart from *C. (K.) annulatus* Martin, other age-diagnostic forms such as *Orbulina* sp. (Tf/N9–Recent) and *Lepidocyclina* (*Nephrolepidina*) sp. (Td–Upper Tf) are present. Thus the Sebahat Formation is probably Middle to Upper Miocene (Lower–Upper Tf of Adams 1970) in age.

Ganduman Formation. This is poorly fossiliferous. It is some 5000 ft (1500 m) thick, and an abundance of lignite and plant remains suggests a period of shallowing and very rapid deposition close to a large river mouth with extensive coastal swamps and mangroves, very similar in fact to the coastal environment of the Dent Peninsula today. A few specimens of *Globigerinoides obliquus* Bolli have been found in the lower part of the formation, but they could have been reworked from the Sebahat Formation. The Ganduman is probably late Miocene or early Pliocene in age.

Togopi Formation. This marks a return to shallow marine sedimentation (inner shelf to littoral). It is the youngest unit of the Dent Group and crops out in a curved belt, 2–3 miles (about 4 km) wide, extending from Tambisan Island in the north to the Merah River in the south (Fig. 1). The type locality and section is in the upper reaches of the Togopi River; few exposures are known elsewhere. Dips are low, usually under 10°, towards the north-east, east and south-east around the nose of the Sebahat anticline.

In the river section the boundary with the underlying Ganduman Formation is said to be a rather sharp lithological change from grey sand with pebbly beds up to 1 in (25 mm) thick,

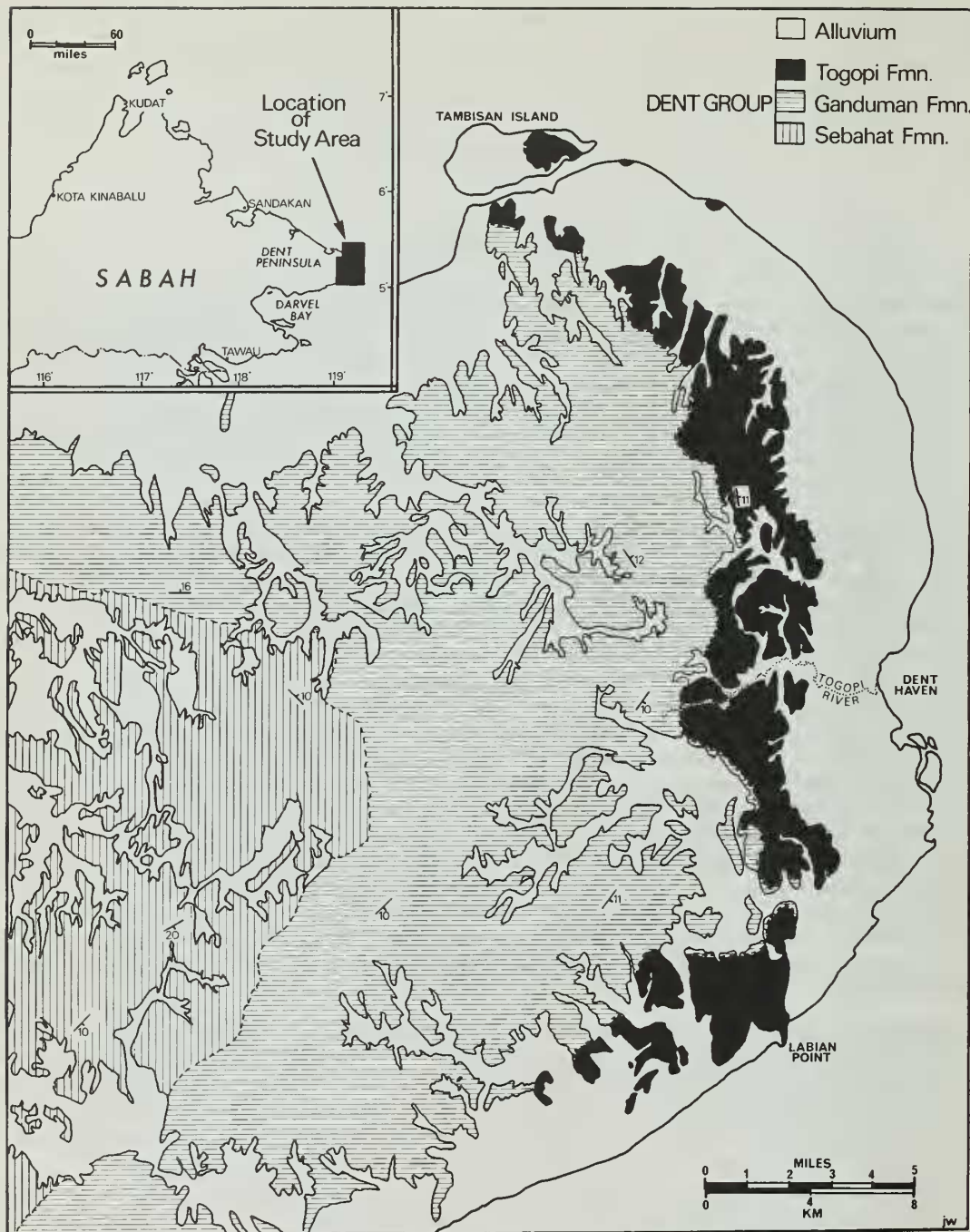


Fig. 1 The stratigraphy of the eastern part of the Dent Peninsula, Sabah (after Haile & Wong 1965).

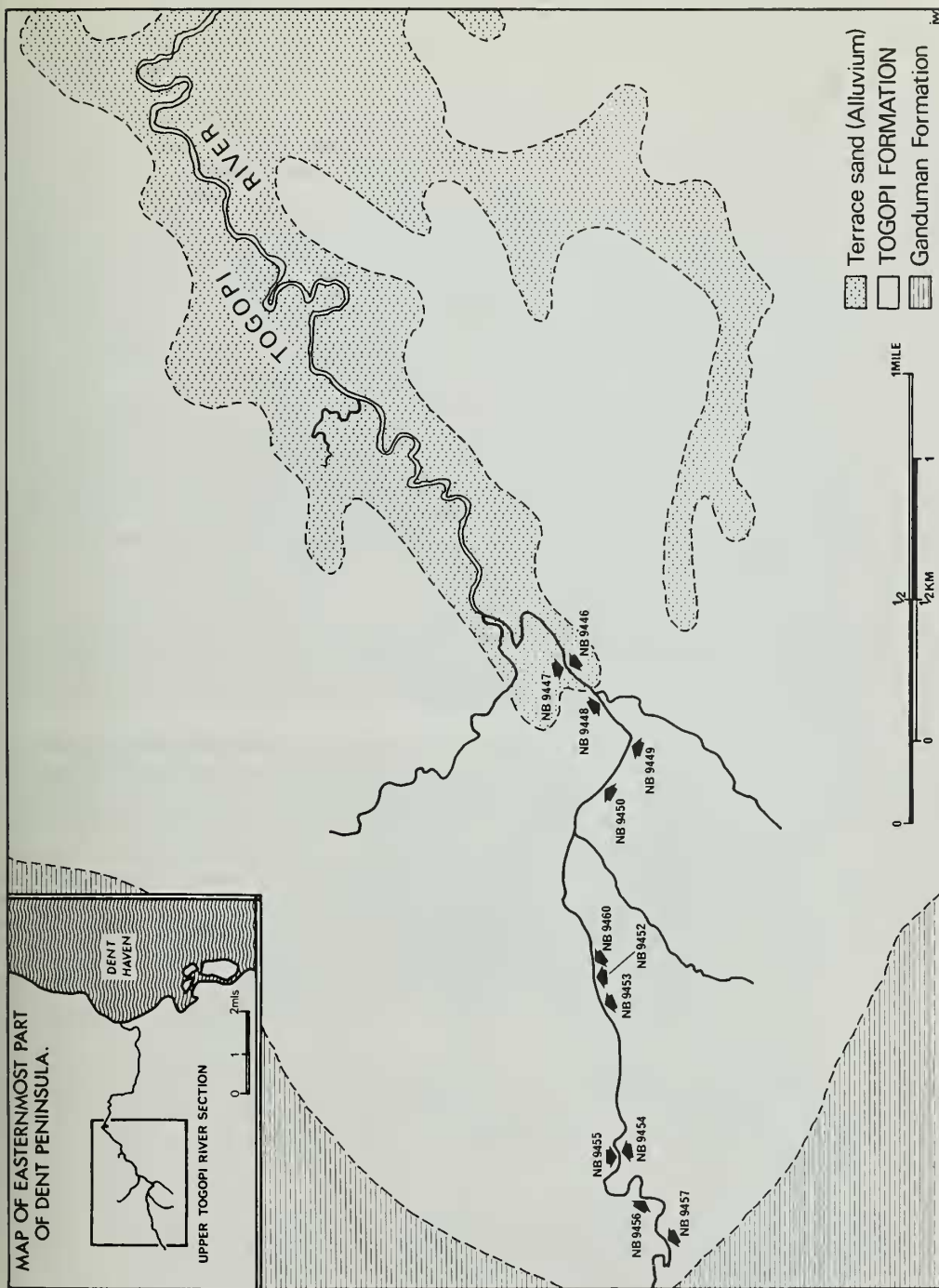


Fig. 2 Map of the upper Togopi River Section, eastern Dent Peninsula, Sabah, showing the location of samples (after Nuttall 1965).

cemented with limonite and full of plant and wood fragments, to the characteristic olive-grey and bluish-grey poorly-bedded clays of the lower Togopi (Haile sample NB 9456/7) in which plant remains are rare according to Haile & Wong (1965: 82). No unconformity has been reported.

Samples NB 9450 up to and including NB 9456/7 were collected from grey to blue-grey sandy clays cropping out in the river banks (Fig. 2). In the area from which NB 9453 was collected there are irregular concretionary beds of fossiliferous grey calcareous sandstone. At an 8 ft (2.4 m) exposure from which NB 9449 was taken the lithology had changed slightly to a blue-grey plastic clay and at NB 9448 a brownish limestone with some 9 in (230 mm) nodules of harder ferruginous limestone was exposed for a thickness of 10 ft (3 m), the whole being covered by a tufa crust. The topmost samples are blue calcareous clays set amongst rubbly limestone rich in corals and reefal debris, the sequence thereafter disappearing under Quaternary alluvium. Assuming an average dip of 5°–10° towards the east and south-east, the type-section must approach 700 ft (210 m) in thickness. The formation is said to attain a maximum thickness of c. 1350 ft (410 m) in the south of the area (Haile & Wong 1965: 81).

Elsewhere, the only other sections studied were by Clements (of SSPC), the results being summarized by Haile & Wong (1965). He had two rentis lines (jungle trails) cut to the north and south of the Togopi River. Along the northern line, the basal beds were reported to be almost undistinguishable from the Ganduman Formation but photogeological evidence suggested an angular unconformity. In the southern cut Clements found a basal conglomeratic sandstone suggesting that the lower boundary of the Togopi represents a shallow marine transgression and is probably slightly unconformable.

Distribution and palaeoecology of the Togopi Foraminifera

Eleven of the best samples collected by Dr N. S. Haile from the Togopi River section were selected for study. A description of these samples, in ascending order of the succession, and their foraminiferal faunas, together with a palaeoecological interpretation, are outlined below. A distribution chart is provided (Table 1, pp. 12–13).

The basal samples, NB 9456 and NB 9457, became mixed in transit and have, therefore, been treated together. Six species were found, of which only *Pseudorotalia catilliformis* (Thalmann) and *Cellanthus biporatus* sp. nov. are common. Sample NB 9455 (see Fig. 2) contains only two species, *P. catilliformis* being dominant. The foraminifera for the most part are badly abraded and corroded, and support Nuttall's (1965) conclusion that the lowermost Togopi was laid down in very shallow, muddy, turbulent, and possibly brackish water close to shore. Alternatively, the microfauna could have been washed in from the sublittoral zone.

Sample NB 9454 contains the first really large fauna. Some 25 species are present, all indicative of shallow inner-shelf conditions. Ten species of the Miliolidae occur (see Table 1), though none of them are common, together with five species of the Elphidiidae, the first species of *Lagena* and *Operculina ammonoides* (Schröter). By far the largest elements in this fauna, however, are the larger rotaliids, *Pseudorotalia catilliformis* (Thalmann) still remaining dominant. NB 9453 is a hard calcareous sandstone which has been disaggregated and also examined by means of thin sections. Although only 10 species have been identified with certainty it appears to contain a similar fauna to NB 9454. Samples NB 9460 and NB 9452 were from approximately the same horizon although the latter (see Fig. 2) was collected some distance to the west of NB 9460; their faunas, however, are quite different. NB 9460 yielded 27 species, dominated almost entirely by large members of the Rotaliidae (common *Asterorotalia pulchella* (d'Orbigny) and *Pseudorotalia* spp.) and members of the Elphidiidae; only one miliolid was found (*Quinqueloculina curta* Cushman), but the first planktonic foraminifera occur (see Table 1). Fifty-seven species have been recorded from NB 9452. Here the fauna is characterized by inner-shelf larger foraminifera which today live on stable substrates, often associated with sea-grass and marine algae down to a depth of about 30 m (usually, however, about 10 m). Our four main species of the Nummulitidae (*Nummulites* cf. *amplicuneatus* (Cole), *N. tamanensis* (Vaughan & Cole), *Operculina ammonoides* (Schröter) and *O. bartschi* Cushman) make up the bulk of the fauna together with very large numbers of *Alveolinella quoyi* (d'Orbigny) and a few representatives of *Amphistegina* and *Hetero-*

stegina (see Table 1). The largest diversity of the Elphidiidae (nine species) also occurs in this sample; there are also abundant specimens of *Florilus asanoi* nom. nov.

Samples NB 9450 and NB 9449 probably represent sediments from the deepest, most open water locally present in 'Togopi times', though it is doubtful if a depth of 30 m was ever exceeded (Nuttall 1965: 163). Here the foraminiferal fauna attains its greatest diversity, 78 and 86 species respectively. The agglutinating element, never strong, reaches its acme, and the Bolivinitidae, usually signifying deeper-water conditions, make their only significant appearance. In NB 9449, moreover (see Table 1), the 11 species of *Lagena* found in the Togopi Formation occur together in large numbers, while both the Miliolidae and Rotaliidae attain their largest diversity, 24 and 28 species, respectively. The algal-dwelling *Calcarina hispida* Brady is a significant member of the fauna in NB 9450, while at NB 9449 many attached species such as *Cymbaloporella* spp. may indicate the presence of seaweed, associated with patch reefs. NB 9448 is a badly leached sample containing few recognizable species.

The uppermost samples present in the Togopi River section may signify a return to shallower water with a build-up of coral reef-patches. A significant proportion of these samples is made up of broken coral (probably transported) and it may be doubted whether true coral reefs occurred in this area at the time. Nevertheless, the lack of planktonic foraminifera compared with Recent shallow-water samples taken in Darvel Bay (H. Buckley, BM(NH), personal communication) is puzzling unless one postulates either a barrier (? coral-reef) to the open sea and thus reduced circulation, or a much higher sedimentation rate than at present. Samples NB 9447 and NB 9446 have 40 and 11 species respectively. Their preservation and often delicate nature suggests that they are life assemblages (cf. the broken corals). Significantly, the large species of *Pseudorotalia*, *Ammonia annectens* (Parker & Jones), *Asterorotalia inspinosa* Huang, and the previously almost ubiquitous *Asterorotalia pulchella* (d'Orbigny) are absent and have been replaced by smaller rotaliids such as *Ammonia beccarii* (Linnaeus) var. *tepida* (Cushman), *A. takanabensis* (Ishizaki) and *Pararotalia* cf. *nipponica* (Asano) (see Table 1). The Elphidiidae remain common to the end of the section, in particular *Elphidiella indopacifica* Germeraad.

Age of the Togopi Formation

Planktonic foraminifera. Only very few, usually immature, individuals, belonging to six species, were found in samples NB 9460 to NB 9447. These are:

Species	Range (after Blow 1969)
<i>Hastigerina siphonifera</i> (d'Orbigny)	N12-N23
<i>Globigerina bulloides</i> d'Orbigny	N16-N23
<i>Globigerina quinqueloba</i> Natland	N17-N23 (after Parker 1967)
<i>Globigerinoides ruber</i> (d'Orbigny)	N16-N23
<i>Globiginoides sacculifer</i> (Brady)	N6-N23
<i>Globigerinita glutinata</i> (Egger)	N16-N23

The upper part of the Togopi Formation cannot, therefore, be older than late Miocene (Zones N16/17).

Benthic foraminifera. Our taxonomic study of the Togopi foraminifera has enabled us to search the literature and establish a tentative stratigraphical distribution for 119 benthic species. There are, of course, a number of difficulties in determining overall ranges, not least of which is the impossibility of verifying original age determinations where accepted age-diagnostic species are absent.

Fig. 3 shows the distribution of the 15 species, thought to be extinct,¹ which occur in the Togopi Formation. Some may ultimately prove to be of importance stratigraphically and are discussed below in conjunction with the work of Billman & Kartaadipura (1975). *Nummulites tamanensis* (Vaughan & Cole), characterized by its trabeculae-like structures, is very distinctive, but its only previous record is from the Miocene of Trinidad. *Nummulites* cf. *amplicuneatus* (Cole) resembles a number of Plio-Pleistocene species from Bikini Atoll (Cole 1954). *Amphistegina* cf. *wanneriana*

¹ But see Postscript, p. 106.

Fischer, to which our poorly-preserved specimens are tentatively assigned, has been previously reported only from the Pliocene of Ceram and Soemba, Indonesia. However, *Brizalina amygdalaeformis* (Brady) *iokiensis* (Asano), *Asterorotalia inspinosa* Huang and *Cellanthus adelaidensis* (Howchin & Parr) occur in the Togopi with some frequency, have all been recorded more often by previous workers, and do not appear to have been found in post-Pliocene sediments. None are found in the uppermost samples (Fig. 3), thus suggesting that these beds may be of Lower Pleistocene age. Nevertheless, two important species, both ranging from Miocene to Plio-Pleistocene, namely *Pseudorotalia catilliformis* (Thalmann) and *Cribrononion tikutoensis* (Nakamura), are also absent from the upper Togopi. The distribution of all five species may, therefore, be facies-controlled. Finally, five new species are listed in Fig. 3.

SPECIES	SAMPLE NO										
	NB 9456/7	NB 9455	NB 9454	NB 9453	NB 9460	NB 9452	NB 9450	NB 9449	NB 9448	NB 9447	NB 9446
<i>Nummulites cf. ampicuneatus</i> ¹											
<i>Nummulites tamanensis</i> ¹											
<i>Amphistegina cf. wanneriana</i> ²											
<i>Asterorotalia inspinosa</i> ²											
<i>Brizalina amygdalaeformis iokiensis</i> ²											
<i>Cellanthus adelaidensis</i> ²											
<i>Ammania togapiensis</i> sp. nov. ³											
<i>Cribrononion tikutoensis</i> ³											
<i>Pseudoeponides japonicus</i> ³											
<i>Pseudarotalia catilliformis</i> ³											
<i>Bolivina sabahensis</i> sp. nov. ⁴											
<i>Cellanthus biperforatus</i> sp. nov. ⁴											
<i>Cellanthus hailei</i> sp. nov. ⁴											
<i>Cribroraphidium dentense</i> sp. nov. ⁴											
<i>Textilina subrectangularis</i> sp. nov. ⁴											

Fig. 3 The distribution of extinct species of foraminifera within the Togopi Formation. Sample numbers are arranged in ascending stratigraphical order, left to right.

¹ Species previously not known in post-Miocene deposits.

² Species previously not known in post-Pliocene deposits.

³ Species previously not known in post-Plio/Pleistocene deposits.

⁴ Species known only from the Togopi Formation (presumed extinct).

In 1969, van der Vlerk & Bannink attempted to show that the genus *Operculina* could be used to determine the age of a deposit using an analogous biometric method to that previously employed with *Lepidocyclina*. The results obtained from testing their hypothesis with two species of *Operculina* from the Togopi Formation are given in detail on p. 90. Although van der Vlerk & Bannink used only *Operculina* for their study, we endeavoured to extend their method to species of *Operculinoides* (= *Nummulites*). *Operculina ammonoides* (Schröter) and *Nummulites cf. ampicuneatus* (Cole) both gave Upper Pliocene results, which may be good evidence that sample NB 9452, if not the whole of the Formation, is of that age; unfortunately *Operculina bartschi* Cushman and *Nummulites tamanensis* (Vaughan & Cole) gave early Miocene and late Eocene dates respectively. Other species from rocks of known age measured for comparative purposes also gave conflicting results (see p. 91 and Fig. 63).

Billman & Kartaadipura (1975) have published a zonation, based on benthonic foraminifera, for the Miocene to Recent sediments of the Kutei Basin, east Borneo. As this area is little more

than 400 miles (650 km) to the south of the Togopi River and contains very similar shallow water deposits to the Dent Group, their paper is of great importance in the present context.

The Kutei Basin zonation is reproduced in Fig. 4. Billman & Kartaadipura define the upper limit of each zone by the local extinction levels of the zonal species. Their uppermost zone is defined by the range of *Calcarina* spp. above the extinction level of *Ammonia ikebei* (Inoue & Nakaseko). Other important markers are *Pseudorotalia conoides* (d'Orbigny) [= *P. schroeteriana* (Parker & Jones), see p. 78] and *Asterorotalia pulchella* (d'Orbigny). N22/23 planktonic foraminifera and NN19/21 (Pleistocene–Recent) nannoplankton were also found. In the Togopi Formation, *Calcarina hispida* Brady, *P. schroeteriana* and *A. pulchella* occur almost throughout the section, *A. pulchella* being ubiquitous except in the highest two samples.

Smaller Benthic Foram. Zone	Other Important Benthic Zonal Markers	Planktonic Foram. Zone (BLOW, 1969)	Calcareous Nannoplankton Zone	Age
CALCARINA	PSEUDOROTALIA CONOIDES ASTEROROTALIA PULCHELLA	N22/23	NN19/21	PLEISTOCENE – RECENT
AMMONIA IKEBEI		?	?	PLIO-PLEISTOCENE
ASANOINA	PSEUDOROTALIA INDOPACIFICA var. ELPHIDIUM SP. 14 SIGMOIDELLA SP. (lower part only)	?	?NN12/16	PLIOCENE
PSEUDOROTALIA CATILLIFORMIS		N15/17	NN11	LATE MIOCENE
AMMONIA YABEI — — ? — —			NN9/11	
		N13/14	NN7/8	MIDDLE MIOCENE

Fig. 4 Correlation of Smaller Benthic Foraminifera Zones with Plankton Zones in the offshore Kutei Basin, Indonesian Borneo (based on Billman & Kartaadipura 1975).

The *Ammonia ikebei* Zone, which lacks age-diagnostic plankton, is assigned a Plio-Pleistocene age on its stratigraphic position. Its top is placed at the highest occurrence of *Ammonia ikebei* [non *A. ikebei* (Inoue & Nakaseko), = *A. togopiensis* sp. nov., see p. 71]. This species is found in both the highest and lowest samples of the Togopi River section (Fig. 3), but is not known to be living today.

Nannoplankton and planktonic foraminifera are also rare in the preceding *Asanoina* Zone, but evidence from wells farther to the south suggests a Pliocene age for this zone. We do not have an *Asanoina* species like that figured by Billman & Kartaadipura (pl. 1, fig. 3), but the other important zonal markers, *Pseudorotalia indopacifica* (Thalmann) var. [a trend to *P. alveiformis* (Thalmann)] seen particularly in Togopi sample NB 9460, see Pl. 10, fig. 8] and *Elphidium* sp. 14 [= *Cellanthus adelaidensis* (Howchin & Parr), see p. 83] occur in the Togopi Formation. *C. adelaidensis* would seem to be a good marker for the Pliocene (see above and Fig. 3). *Sigmoidella* sp. [= *S. elegantissima* (Parker & Jones)] is used by Billman & Kartaadipura to subdivide this zone (Fig. 4), its highest occurrence being within the lower half. However, our survey shows that this species probably ranges from Miocene to Recent.

The *Pseudorotalia catilliformis* Zone spans the time occupied by the deposition of the sediments in which the Kutei oil and gas reservoirs are now found. These sediments are indicative of very shallow water, nannoplankton and pelagic foraminifera are rare, but deeper-water intercalations prove a late Miocene age. In the Togopi Formation, *P. catilliformis* occurs in samples NB 9456/7 to NB 9452 (? NB 9450), after which it disappears (see Fig. 3). This may indicate either a facies change or extinction as the species does not appear to be living today. We have found, however, that specimens provided by Billman from the *Asanoina* Zone and labelled *P. tikutoensis* (Nakamura) are synonymous with *P. catilliformis*. This species must, therefore, as at Togopi, occur in

[illegible]

rocks younger than late Miocene. We do not have *Ammonia yabei* (Ishizaki), the zonal fossil of Billman & Kartaadipura's oldest zone, which they date as late Miocene (? M. Miocene) (Fig. 4). We cannot, therefore, relate the Togopi Formation to any one of Billman & Kartaadipura's zones, but can only state that it is probably younger than the *Ammonia yabei* Zone, a dating which is substantiated by the post-N15 age given by our planktonic foraminifera and by the accumulated micropalaeontological evidence of the underlying formations of the Dent Group (see p. 5). Almost all the zone-fossils and other important benthic markers from every zone from *Pseudorotalia catilliformis* (late Miocene) to *Calcarina* (Pleistocene/Recent) occur together in our samples. More work is, therefore, needed before a regionally reliable benthic zonation can be erected. Nevertheless, some of Billman & Kartaadipura's marker species, together with those listed in Fig. 3, may still be of more than local value.

After this paper was completed, a single specimen of *Lepidocyclus* was discovered in sample NB 9452, but in spite of diligent searching through the remainder of the unpicked residue, no further specimens were found. Dr C. G. Adams (personal communication) has referred to it as *Lepidocyclus* (*Nephrolepidina*) aff. *multilobata* Gerth. The embryonic apparatus, he reports, is fairly primitive and not lying in the same plane as the equatorial chambers which are not, therefore, visible in the sectioned specimen. The specimen was determined only on external morphological features.

This find means either that the Togopi Formation is of late Miocene age, at least in part, or that the specimen of *Lepidocyclus* is reworked. The former alternative is not thought tenable: the geographical and stratigraphical position of the Togopi Formation (see above and Haile & Wong 1965) and the evidence of the Mollusca (see p. 3) strongly militate against any suggestion that it may be of Miocene age. We must, therefore, assume, for the present at least, that the single specimen of *Lepidocyclus* is reworked and that the Togopi is mainly Pliocene in age. It follows that some of the other larger foraminifera in NB 9452 may also be reworked and this may partly explain the discordant results of our 'Factor E' analysis on *Operculina/Nummulites*.

The Togopi Formation, it is concluded, is mainly of Pliocene age although its upper part could perhaps be slightly younger.

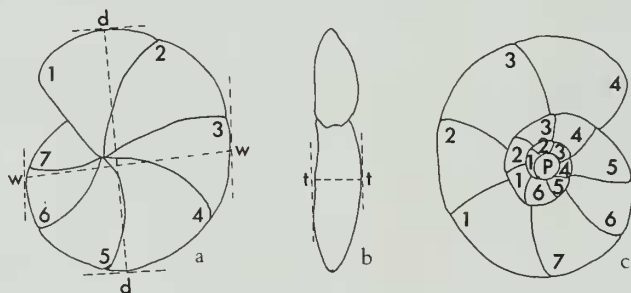


Fig. 5 A hypothetical foraminifer showing dimensions measured (Figs 5a, b: d = diameter, w = width, t = thickness) and method of counting chambers (Fig. 5a, in last whorl; Fig. 5c, in first, second and third whorls; P = proloculus).

Systematics

Synonymies have been restricted to records from the Indo-West Pacific and to important name changes or redefinitions from outside the area. The Indo-West Pacific is here defined as the area bounded by Japan and the Red Sea in the north, by Australia and New Zealand in the south, East Africa in the west and Hawaii in the east. Rare and indeterminate species, although figured, are dealt with only briefly.

We have wherever possible compared our material directly with that of other authors and extensive reference has been made to the following important collections housed in the BM(NH): H. B. Brady ('Challenger'), W. B. Carpenter, A. C. Collins, E. Heron-Allen & A. Earland, F. W. Millett and W. K. Parker & T. R. Jones. Syntypes have been borrowed, where necessary, from the U.S. National Museum.

Dimensions, given under the heading 'Variation', are the maxima for the smallest and largest specimen (Figs 5a, b) except where otherwise stated. Chamber counts in both planispiral and trochoid forms exclude the proloculus (Fig. 5c). Counts for the last whorl commence, of course, with the final chamber (Fig. 5a).

The classification followed here is that of the Treatise on Invertebrate Paleontology (Loeblich & Tappan 1964) except that the genus *Operculina* is reinstated, *Amphisorus* and *Sphaerogypsina* are regarded as junior synonyms of *Marginopora* and *Gypsina* respectively, and *Tretomphalus* is considered merely to be the planktonic reproductive phase of species of *Rosalina* and *Cymbaloporeta*. Finally, the 'post-Treatise' genus *Textilina* (Nørvang 1966) is used for two species previously referred to *Textularia*.

All figured specimens are deposited in the British Museum (Natural History), London, and their registered numbers are cited in the plate and figure explanations. A duplicate set of specimens has been deposited with the Geological Survey of Malaysia, Ipoh, Malaya.

Family ATAXOPHRAGMIIDAE Schwager, 1877

Subfamily VERNEULININAE Cushman, 1911

Genus *TEXTILINA* Nørvang, 1966

Type-species: *Textularia stricta* Cushman, 1911.

Textilina conica (d'Orbigny)

Pl. 1, figs 1a, b

1839 *Textularia conica* d'Orbigny: 143; pl. 1, figs 19, 20.

1966 *Textilina conica* (d'Orbigny) Nørvang: 9; pl. 1, figs 5-7; pl. 2, fig. 8.

MATERIAL. 5 specimens. NB 9449, 9450.

VARIATION. Length 0.50-0.63 mm, width 0.72-1.08 mm, thickness 0.45-0.80 mm.

REMARKS. Apparently very variable in both length (height) and thickness of the test. A Recent suite of specimens from Darvel Bay, Sabah, in the collections of the BM(NH) shows similar variation.

This species possesses a triserial initial part and a coarsely perforate wall characteristic of *Textilina* (Nørvang 1966: 6-9). The suprageneric position of *Textilina* and all other members of the Textulariina is now in urgent need of revision (Murray 1973).

RANGE. Pliocene (Asano 1950b) to Recent.

Textilina subrectangularis sp. nov.

Pl. 1, figs 2a-c

DIAGNOSIS. A moderately compressed species of *Textilina*. Chambers rarely inflated; most sutures flush, moderately inclined. Test characteristically subrectangular in apertural view.

NAME. From the shape of the test.

HOLOTYPE. BM(NH) reg. no. P50062 from sample NB 9449.

MATERIAL. 36 specimens. NB 9449, 9450, 9452, 9454.

DESCRIPTION (Holotype). Test free, agglutinating, tapering, moderately compressed, subrectangular in apertural view, slightly curved in edge view. Initial chambers subrounded, last few chambers broad and strongly arched. Sides of test almost flat, peripheries broadly rounded. Chambers 9 in each series; sutures mainly flush and difficult to discern, initially horizontal, then inclined at about 30° to the axial plane. Aperture a short rectangular slit at the base of the last chamber.

DIMENSIONS (Holotype). Length 0.70 mm, breadth 0.40 mm, thickness 0.27 mm.

VARIATION. Size range of paratypes: length 0.35–0.85 mm, breadth 0.29–0.40 mm, thickness 0.18–0.30 mm. In a few specimens the later chambers are slightly inflated and the sutures correspondingly depressed. The number of chambers varies between 8 and 10 pairs.

REMARKS. A number of specimens have been examined in thin section and by scanning electron microscopy. There was no sign of an initial planispiral coil, rather the first three chambers following the proloculus appeared in all cases to be arranged triserially, the remainder biserially. This feature, together with the observed presence of minute perforations in the wall of the test, place the species in the genus *Textilina* (Nørvang 1966).

Textilina subrectangularis sp. nov. has been compared with Heron-Allen & Earland's type-material of the Recent *Textularia foliacea* from the Kerimba Archipelago, East Africa (BM(NH) nos 1955:10:21:429–442). Both species have approximately the same number of chambers, but the former is smaller, thicker and has less inflated chambers and depressed sutures, thus lacking the foliaceous outline of the latter. Moreover, the sides of *T. subrectangularis* are characteristically flattened and the peripheries broadly rounded. *Textularia malaccaensis* Le Roy, originally described from the Miocene of Sumatra (Le Roy 1939: 230; pl. 9, figs 4, 5), has more highly inclined sutures and is much more compressed than the present species.

Subfamily VALVULININAE Berthelin, 1880

Genus *CLAVULINA* d'Orbigny, 1826

Type-species: *Clavulina parisiensis* d'Orbigny, 1826.

Clavulina pacifica Cushman

Pl. 1, figs 3a, b

- 1884 *Clavulina angularis* d'Orbigny; Brady: 396; pl. 48, figs. 22–24b (*non* d'Orbigny, 1826).
 ? 1921 *Clavulina angularis* d'Orbigny; Cushman: 155; pl. 31, fig. 3.
 1924 *Clavulina pacifica* Cushman: 22; pl. 6, figs 7–11.
 1937 *Clavulina pacifica* Cushman; Cushman: 25; pl. 3, figs 17a–18b.
 1952 *Clavulina pacifica* Cushman; Uchio: 151; pl. 6, figs 4a, b.
 1954 *Clavulina pacifica* Cushman; Cushman, Todd & Post: 332; pl. 83, fig. 19.
 1959 *Clavulina pacifica* Cushman; Graham & Militante: 32; pl. 2, figs 17a, b.
 1960 *Clavulina pacifica* Cushman; Barker: 98; pl. 48, figs 22–24b (after Brady).
 1964 *Clavulina pacifica* Cushman; Rocha & Ubaldo: 36; pl. 1, figs 16, 17.
 1965 *Clavulina pacifica* Cushman; Moura: 14; pl. 1, fig. 6.
 1970 *Clavulina pacifica* Cushman; Murray: 63 (list); figs 5A, B.

MATERIAL. 18 specimens. NB 9447, 9448, 9449, 9450, 9454.

VARIATION. Length 0.55–1.65 mm, width 0.30–0.43 mm; number of uniserial chambers 3–10.

DISTRIBUTION. *Fossil*: The only previous fossil record appears to be from the sub-Recent of northern Timor, alluvium in the 2-metre raised coastal plain (Rocha & Ubaldo 1964). *Recent*: Widespread in the western Pacific. Murray (1970) records it from the Abu Dhabi lagoon, Persian Gulf; Moura (1965) from the coast of Mozambique.

Family NUBECULARIIDAE Jones, 1875

Subfamily OPHTHALMIDIINAE Wiesner, 1920

Genus *EDENTOSTOMINA* Collins, 1958

Type-species: *Miliolina cultrata* Brady, 1879.

Edentostomina cf. *millettii* (Cushman)

Figs 6–8; Pl. 3, figs 4a, b

cf. 1898 *Miliolina durrandii* Millett (*pars*): 268; pl. 6, figs 8–10 only.

cf. 1917 *Biloculina millettii* Cushman: 81; pl. 34, figs 4, 5.

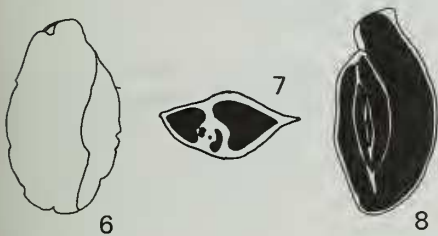
MATERIAL. 9 specimens. NB 9449, 9450, 9452.

VARIATION. Length 0.66–1.55 mm, width 0.27–0.91 mm, thickness 0.13–0.53 mm.

REMARKS. This carinate, moderately inflated species with an edentate oval aperture is unfortunately usually found broken and infilled with pyrite in the Togopi samples. The best-preserved adult specimen, however, appears to be triloculine as three chambers are visible on one side and two on the other (see Fig. 6; Pl. 3, fig. 4a). This arrangement is nevertheless neither triloculine nor typically miliolid, as can be seen from the drawing of the half-section (Fig. 7). The coiling is more or less planispiral; the chambers few, the last two being added at approximately 180°. We therefore follow Loeblich & Tappan (1964: C448) in placing *Edentostomina* within the Ophthalmitiinae.

Of the species of *Edentostomina* so far described, the Togopi specimens are most like *E. millettii* (Cushman), though the paucity of our material precludes any certainty that it is conspecific. Cushman (1917: 81), who introduced the name for the 'biloculine form' of *Miliolina durrandii* Millett (1898: 268; pl. 5, figs 8–10 only), stated that the aperture was toothed, a statement which he repeated later but did not substantiate with his figure (Cushman 1932: 66; pl. 15, fig. 4b). This anomaly was not commented on by Collins (1958: 370), who when diagnosing his new genus considered that '... the main point of difference from *Triloculina* s. str. [was] the large oval and edentate aperture'.

DISTRIBUTION. The genus is widespread in the Indo-Pacific at the present day. This is possibly its first authenticated fossil record.



Figs 6–8 *Edentostomina* cf. *millettii* (Cushman).
6, P50094. Reverse side of specimen illustrated in Pl. 3, fig. 4a. Sample NB 9452. $\times 20$.
7, P50236. Section showing the almost planispiral nature of the coil. Sample NB 9452. $\times 40$.
8, P50237. Equatorial section. Sample NB 9450. $\times 20$.

Subfamily **SPIROLOCULININAE** Wiesner, 1920

Genus **SPIROLOCULINA** d'Orbigny, 1826

Type-species: *Spiroloculina depressa* d'Orbigny, 1826.

Spiroloculina cf. *angulata* Cushman

Fig. 9; Pl. 1, fig. 4

cf. 1917 *Spiroloculina grata* Terquem var. *angulata* Cushman: 36; pl. 7, figs 5a, b.

MATERIAL. 3 specimens. NB 9447.

VARIATION. Length 0.85–0.90 mm, width 0.50–0.60 mm, thickness 0.20–0.23 mm. Up to 12 ribs on last chamber, number of chambers 6–10.

REMARKS. Considerable confusion exists between *S. angulata* Cushman and *S. antillarum* d'Orbigny. In 1944 Cushman & Todd redefined them, primarily on the appearance of their tests in apertural view. The chambers of the latter (1944: 44) were said to be typically more inflated than those of the former which has rounded peripheries. *S. angulata* (1944: 51) is thinner and, as the name implies, has an angled periphery often with a pronounced median ridge. Costation, otherwise, is similar in the two forms and the shape of the test is very variable in both.

On the strength of this dissimilarity, Cushman & Todd conclude that *S. antillarum* is restricted to the Recent of the western Atlantic (it was originally described by d'Orbigny in 1826 from

Cuba), while *S. angulata* is found widely in the Indo-Pacific. However, since their work appeared Albani (1965) has found *S. antillarum* in south-east African waters, while several authors have recorded it from the coasts of India.

As we have only one complete specimen, we are not able to clarify the situation to any great extent. We can say, however, that our form is very similar to that illustrated by Brady (1884) as *S. grata* (non Terquem 1878) from Shell Cove, Port Jackson, Australia, and since transferred to *S. angulata* by Barker (1960). Both Brady's figures (pl. 10, figs 22a, b) and our own, however, lack the truly angular periphery shown in the holotype (Cushman & Todd 1944: pl. 7, fig. 18b).

Spiroloculina angulata has a fossil record back to the Pliocene (Asano 1951), whereas *S. antillarum* is known only from the Recent.

Spiroloculina communis Cushman & Todd *incisa* Cushman

Pl. 1, fig. 5

1921 *Spiroloculina grateloupi* d'Orbigny var. *incisa* Cushman: 397; pl. 78, fig. 5.

1944 *Spiroloculina communis* Cushman & Todd var. *incisa* Cushman; Cushman & Todd: 64; pl. 9, figs 1-3, 6.

1951 *Spiroloculina communis incisa* Cushman; Asano: 13, text-figs 89, 90.

MATERIAL. 5 specimens. NB 9449.

VARIATION. Length 0.39-0.83 mm, width 0.24-0.57 mm, thickness 0.14-0.33 mm.

REMARKS. The holotype appears to be a very large individual, about 3.7 mm long. Other specimens, however, illustrated by Cushman & Todd (1944), especially a topotype (figs 1a, b), are identical in size and appearance to those from the Togopi Formation. Evidently the size range is considerable.

Cushman (in Cushman & Todd 1944) transferred *incisa* as a variety to *S. communis* Cushman & Todd, from which it differs only in having the peripheral margins of the chambers raised above the succeeding chambers.

DISTRIBUTION. *Fossil*: Pliocene of Japan (Asano 1951). *Recent*: The Philippines (Cushman 1921, Cushman & Todd 1944).

Spiroloculina eximia Cushman

Pl. 1, fig. 6

1922 *Spiroloculina eximia* Cushman: 61; pl. 11, fig. 2.

1924 *Spiroloculina eximia* Cushman; Cushman: 56; pl. 21, fig. 2.

1929 *Spiroloculina eximia* Cushman; Cushman: 42; pl. 8, figs 7a, b.

1932 *Spiroloculina eximia* Cushman; Cushman: 39; pl. 10, figs 2, 3.

1944 *Spiroloculina eximia* Cushman; Cushman & Todd: 46; pl. 6, figs 36a-38b.

1956 *Spiroloculina eximia* Cushman; Bhatia: 18; pl. 1, figs 14a, b.

1964b *Spiroloculina eximia* Cushman; Rocha & Ubaldo: 647 (list); pl. 2, figs 7, 8.

MATERIAL. 7 specimens. NB 9447, 9450.

VARIATION. Length 0.44-0.74 mm, width 0.28-0.45 mm, thickness 0.20-0.28 mm.

DISTRIBUTION. A common species in the Recent tropical western Pacific, but known also from the west coast of India (Bhatia 1956, Rocha & Ubaldo 1964b). It was originally described from the Tortugas, off Florida, though further records from the Caribbean appear to be lacking. The Togopi specimens are believed to constitute the first fossil record.

Spiroloculina lucida Cushman & Todd

Pl. 1, fig. 7

1944 *Spiroloculina lucida* Cushman & Todd: 70; pl. 9, figs 30-31b.

1951 *Spiroloculina lucida* Cushman & Todd; Asano: 15, text-figs 99, 100.

1956a *Spiroloculina lucida* Cushman & Todd; Asano: 68; pl. 7, figs 5a, b.

MATERIAL. 3 specimens. NB 9447, 9449, 9452.

VARIATION. Length 0.46–0.90 mm, width 0.30–0.59 mm, thickness 0.21–0.42 mm.

REMARKS. Only the figured specimen is complete. However, enough is preserved of the others to show that the peripheral margins of the older chambers always project to form weak ridges. This feature is less apparent in the holotype (Cushman & Todd 1944: pl. 9, fig. 31a) than in the paratype (1944: pl. 9, fig. 30). The main difference between *S. lucida* and *S. communis* (and its sub-species) is that in typical members of the latter group the periphery is flat or more commonly concave, while in the former it is convex.

DISTRIBUTION. *Fossil:* Pliocene of Pacific coast of Japan (Asano 1951). *Recent:* Western Pacific from Japan (Asano 1956a) southwards to south-eastern Australia (Cushman & Todd 1944).

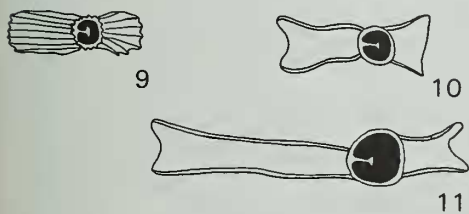


Fig. 9 *Spiroloculina* cf. *angulata* Cushman. P50064. Apertural view of specimen figured on Pl. 1, fig. 4. Sample NB 9447. $\times 40$.

Figs 10, 11 *Spiroloculina manifesta* Cushman & Todd. Apertural views of specimens figured on Pl. 1, figs 8, 9. Sample NB 9450. $\times 40$. 10, P50068, megalospheric form. 11, P50069, microspheric form.

Spiroloculina manifesta Cushman & Todd

Figs 10, 11; Pl. 1, figs 8, 9

- 1917 *Spiroloculina canaliculata* d'Orbigny; Cushman : 30; pl. 4, figs 1–3 (*non* d'Orbigny 1846).
 1921 *Spiroloculina depressa* d'Orbigny; Cushman : 394; pl. 81, fig. 2 only (*non* d'Orbigny 1826).
 1921 *Spiroloculina canaliculata* d'Orbigny; Cushman : 395; pl. 80, fig. 3a, b.
 1932 *Spiroloculina grateloupi* d'Orbigny; Cushman (*pars*) : 34; pl. 8, fig. 9 only (*non* d'Orbigny 1826).
 1944 *Spiroloculina manifesta* Cushman & Todd : 62; pl. 8, figs 26a–28.
 1951 *Spiroloculina manifesta* Cushman & Todd; Asano : 15, text-figs 101, 102.
 1956a *Spiroloculina manifesta* Cushman & Todd; Asano : 68; pl. 7, figs 4a, b, 8a, b.

MATERIAL. 36 specimens. NB 9448, 9449, 9450, 9452.

VARIATION. *Megalospheric form:* length 0.40–1.12 mm, width 0.21–0.73 mm, thickness 0.10–0.25 mm; maximum number of whorls 7. *Microspheric form:* length 1.08–1.70 mm, width 0.70–1.15 mm, thickness 0.18–0.30 mm; maximum number of whorls 9.

REMARKS. Considerable morphological variation exists within the Togopi specimens. The microspheric form tends to be subcircular in side view with the chambers nearly flush; the megalospheric form, on the other hand, is much narrower and often strongly concave in the central portion of the test. In both, however, the margins are keeled, giving a characteristic concave appearance to the periphery when seen in apertural view (Figs 10, 11).

DISTRIBUTION. *Fossil:* Pliocene of Japan (Asano 1951). *Recent:* Cushman & Todd (1944) list its occurrence from the Red Sea and Arabian Coast eastwards to the West Pacific islands. The holotype is from the Philippines.

Subfamily **NODOBACULARIINAE** Cushman, 1927

Genus **VERTEBRALINA** d'Orbigny, 1826

Type-species: *Vertebralina striata* d'Orbigny, 1826.

Vertebralina striata d'Orbigny

Fig. 12

1826 *Vertebralina striata* d'Orbigny : 283, no. 1, modèle 81.

MATERIAL. 2 specimens. NB 9449, 9450.

DIMENSIONS OF FIGURED SPECIMEN. Length 0.56 mm, width 0.43 mm, thickness 0.12 mm.

REMARKS. A very variable species largely owing to the attitude of the later chambers which tend to become uncoiled and rectilinear. Our specimens, although closely coiled, are similar to many examples in the Brady 'Challenger' and Millett collections.

RANGE. Pliocene (Yabe & Asano 1937, Asano 1951c) to Recent.



Fig. 12 *Vertebralina striata* d'Orbigny. P50238.
Side view. Sample NB 9449. $\times 60$.

Family MILIOLIDAE Ehrenberg, 1839

Subfamily QUINQUELOCULININAE Cushman, 1917

Genus *QUINQUELOCULINA* d'Orbigny, 1826

Type-species: *Serpula seminulum* Linné, 1758.

Quinqueloculina contorta d'Orbigny

Figs 13, 14; Pl. 1, fig. 10

1846 *Quinqueloculina contorta* d'Orbigny: 298; pl. 20, figs 4-6.

1951 *Quinqueloculina contorta* d'Orbigny; Asano: 3, text-figs 11-13.

1956a *Quinqueloculina contorta* d'Orbigny; Asano: 58; pl. 7, figs 12a-c.

1963 *Quinqueloculina contorta* d'Orbigny; Matsunaga: pl. 27, figs 9a-c.

1964a *Quinqueloculina contorta* d'Orbigny; Rocha & Ubaldo: 410; pl. 1, figs 1a, b.

Plate 1

Scanning Electron Micrographs

Figs 1a, b *Textilina conica* (d'Orbigny). P50061. Side and apertural views. Sample NB 9449. $\times 60$.

Figs 2a-c *Textilina subrectangularis* sp. nov. P50062. Edge, side and apertural views. **Holotype**, sample NB 9449. $\times 60$.

Figs 3a, b *Clavulina pacifica* Cushman. P50063. Side views. Sample NB 9449. $\times 35$.

Fig. 4 *Spiroloculina* cf. *angulata* Cushman. P50064. Side view. Sample NB 9447. $\times 60$. (See Fig. 9, p. 19.)

Fig. 5 *Spiroloculina communis* Cushman & Todd *incisa* Cushman. P50065. Side view. Sample NB 9449. $\times 60$.

Fig. 6 *Spiroloculina eximia* Cushman. P50066. Side view. Sample NB 9450. $\times 60$.

Fig. 7 *Spiroloculina lucida* Cushman & Todd. P50067. Side view. Sample NB 9452. $\times 60$.

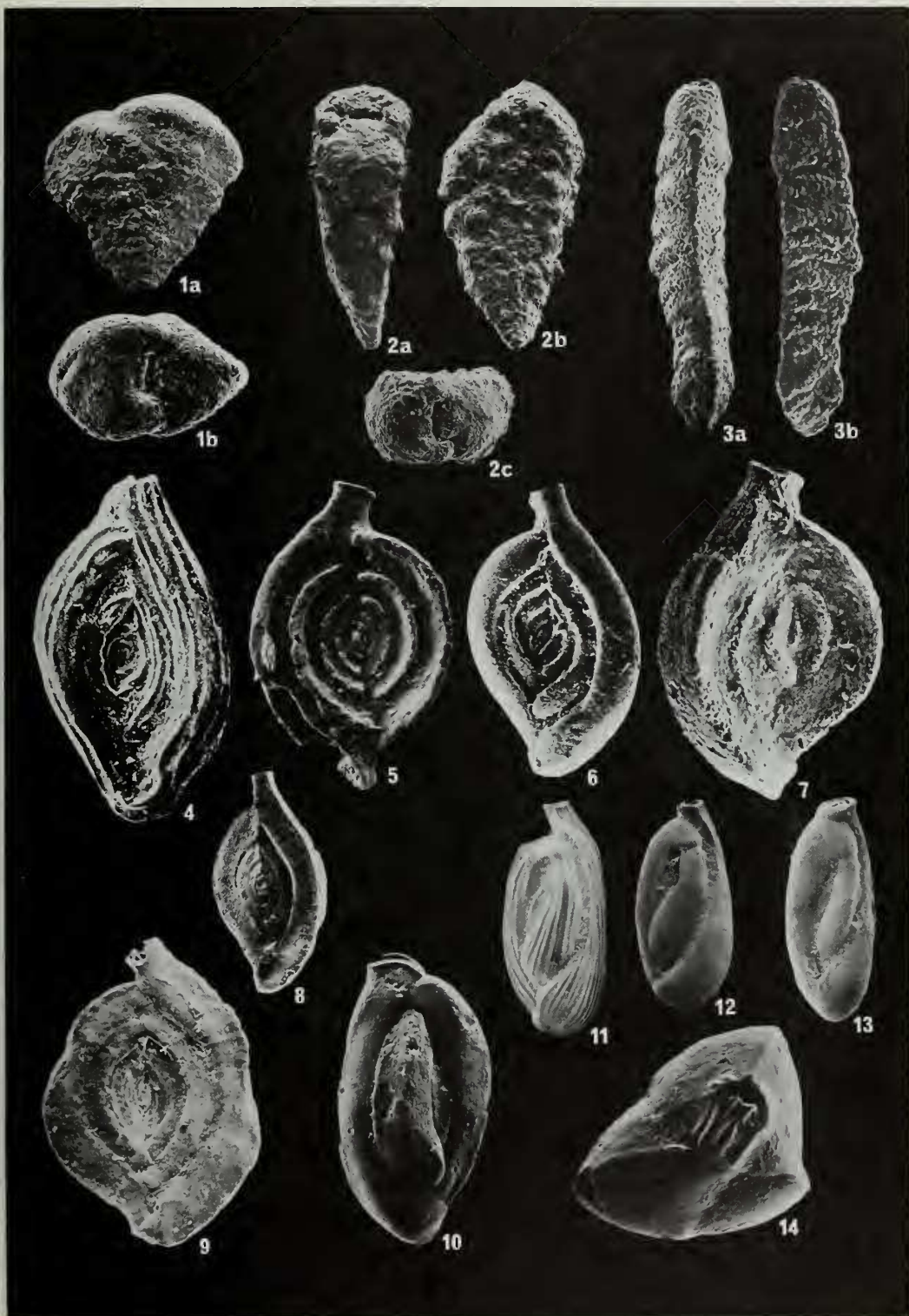
Figs 8, 9 *Spiroloculina manifesta* Cushman & Todd. P50068, P50069. Side views of megalospheric and microspheric forms. Sample NB 9450. $\times 30$. (See Figs 10-11, p. 19.)

Fig. 10 *Quinqueloculina contorta* d'Orbigny. P50070. Side view. Sample NB 9452. $\times 60$. (See Fig. 13, p. 22.)

Figs 11, 12 *Quinqueloculina exsculpta* (Heron-Allen & Earland). P50071, P50072. Side views of striate and smooth forms. Sample NB 9449. $\times 75$.

Fig. 13 *Quinqueloculina tropicalis* Cushman. P50073. Side view. Sample NB 9449. $\times 75$.

Fig. 14 *Quinqueloculina cuvieriana* d'Orbigny. P50074. Apertural view of large specimen; see also Pl. 2, figs 12, 13. Sample NB 9450. $\times 60$. (See Fig. 19, p. 24.)



1968 *Quinqueloculina contorta* d'Orbigny; Chiji & Lopez : 110; pl. 8, figs 9a-c.

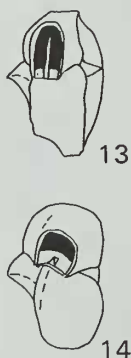
1970 *Quinqueloculina contorta* d'Orbigny; Matoba : 59; pl. 2, figs 6a, b.

MATERIAL. 11 specimens. NB 9452, ? 9453 (rock section), 9454.

VARIATION. Length 0.56-0.90 mm, width 0.31-0.50 mm, thickness 0.21-0.37 mm.

REMARKS. Le Roy (1964 : F20; pl. 3, figs 7, 8) records *Q. contorta* from the Neogene of Okinawa, west Pacific. Because of its well-pronounced striate ornamentation, however, we hesitate to include Le Roy's species within the present synonymy.

In apertural view, the Togopi specimens have either rounded or truncate chamber peripheries (Figs 13, 14). The truncate form is very similar in appearance to that from the Recent of north-east Japan figured by Matoba (1970 : pl. 2, figs 6a, b) and closely resembles d'Orbigny's type-figure (1846 : pl. 20, figs 4-6).



Figs 13, 14 *Quinqueloculina contorta* d'Orbigny.
Contrasting apertural views. 13, P50070.
Specimen illustrated in Pl. 1, fig. 10. 14,
P50239. Sample NB 9452. $\times 50$.

DISTRIBUTION. *Fossil*: Originally described from the Tertiary of Nussdorf in the Vienna Basin (d'Orbigny 1846) it has subsequently been recorded from the Pliocene of Japan (Asano 1951, Matsunaga 1963). *Recent*: Coasts of Japan (Asano 1956a, Chiji & Lopez 1968, Matoba 1970); Diu, north-west India (Rocha & Ubaldo 1964a).

Quinqueloculina curta Cushman
Figs 15a-17b; Pl. 2, figs 10, 11

1898a *Miliolina cuvieriana* (d'Orbigny); Millett : 505; pl. 12, figs 2a, b (*non Quinqueloculina cuvieriana* d'Orbigny 1839).

1917 *Quinqueloculina disparalis* d'Orbigny var. *curta* Cushman : 49; pl. 14, figs 2a-c; text-fig. 30.

1921 *Quinqueloculina curta* Cushman; Cushman : 426; pl. 100, figs 1, 2.

1924 *Quinqueloculina disparalis* d'Orbigny var. *curta* Cushman; Cushman : 60; pl. 22, figs 7, 8.

1931 *Quinqueloculina curta* Cushman; Hada : 80, text-figs 33a-c.

1933 *Quinqueloculina curta* Cushman; Hofker : 98; pl. 3, figs 13-25; text-figs 19, 20.

1937 *Quinqueloculina curta* Cushman; Yabe & Asano : 114; pl. 17, figs 1-4.

1941a *Quinqueloculina* sp. F Le Roy : 71; pl. 5, figs 3, 4.

1941b *Cribrolinoides curta* (Cushman) Le Roy : 113; pl. 1, figs 1-5.

1951 *Cribrolinoides curta* (Cushman); Asano : 9, text-figs 63, 64.

1956a *Quinqueloculina curta* Cushman; Asano : 59; pl. 7, figs 13a, b.

1959 *Quinqueloculina curta* Cushman; Graham & Militante : 44; pl. 5, figs 9a-c.

1963 *Quinqueloculina curta* Cushman; Matsunaga : pl. 26, figs 16a-c.

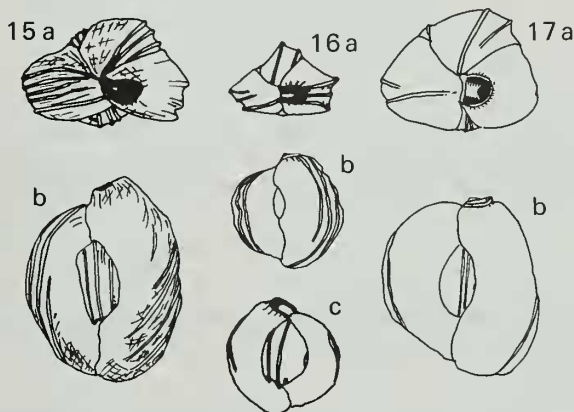
MATERIAL. About 500 specimens. NB 9449, ? 9450, 9452, ? 9453, 9454, 9460.

VARIATION. Length 0.16-2.15 mm, width 0.55-1.62 mm, thickness 0.41-1.50 mm.

REMARKS. Many of the forms illustrated by Hofker (1933 : pl. 3, figs 13-25) are present in the Togopi material. There is gradation in the larger specimens from smooth tests with rounded chambers, carinae being only poorly developed on the chamber peripheries (Figs 17a, b; Pl. 2,

fig. 11), to forms with truncate, strongly carinate peripheries and even secondary reticulate ornament (Figs 15a, b; Pl. 2, fig. 10). Smaller individuals (Figs 16a–c) tend to be very similar to that figured by Graham & Militante (1959).

Cushman & Le Roy (1939) erected a new genus *Cribrolinoides*, with *Quinqueloculina curta* as the type-species, differentiated mainly by the development of a complicated ring-like cribrate aperture. Hofker (1968 : 18) has shown that this trend occurs only in some gerontic microspheric forms, the megalospheric forms having simple apertures. The present material, with the exception of one 'cribrolinoid' specimen, has relatively simple apertures with single or bifid teeth.



Figs 15a–17b *Quinqueloculina curta* Cushman. Overall variation. 15a, b, P50084. Apertural and rear views of specimen illustrated on Pl. 2, fig. 10. 16a–c, P50240. Apertural, rear and front views of small specimen with prominent carinae. 17a, b, P50085. Apertural and rear views of specimen illustrated on Pl. 2, fig. 11. All from sample NB 9449. $\times 15$.

DISTRIBUTION. *Fossil*: Late Tertiary (? Pliocene) of Siberoet Island, Indonesia (Le Roy 1941a); Pliocene of Japan (Asano 1951, Matsunaga 1963); Pliocene (Yabe & Asano 1937) and Plio-Pleistocene (Le Roy 1941b) of Java. *Recent*: This species occurs widely at the present day in the west Pacific Islands from Japan to New Guinea.

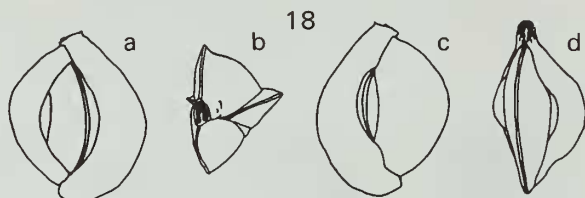
Quinqueloculina cuvieriana d'Orbigny

Figs 19a–c; Pl. 1, fig. 14; Pl. 2, figs 12, 13

- 1839 *Quinqueloculina cuvieriana* d'Orbigny : 190; pl. 11, figs 19–21.
- 1884 *Miliolina cuvieriana* (d'Orbigny) Brady : 162; pl. 5, figs 12a–c.
- ? 1884 *Miliolina auberiana* (d'Orbigny); Brady : 162; pl. 5, figs 8, 9.
- ? 1917 *Quinqueloculina auberiana* d'Orbigny; Cushman : 46; pl. 12, figs 1a–c.
- 1921 *Quinqueloculina lamarckiana* d'Orbigny; Cushman : 418; pl. 87, figs 2a–3c; text-figs 22, 23 (*non* d'Orbigny 1839).
- 1931 *Quinqueloculina lamarckiana* d'Orbigny; Hada : 79, text-figs 32a–c.
- 1932 *Quinqueloculina lamarckiana* d'Orbigny; Cushman : 24; pl. 6, figs 2a–c.
- 1941a *Quinqueloculina* aff. *lamarckiana* d'Orbigny; Le Roy : 71; pl. 5, figs 5, 6.
- 1941b *Quinqueloculina cuvieriana* d'Orbigny; Le Roy : 112; pl. 1, figs 31–33.
- 1951 *Quinqueloculina lamarckiana* d'Orbigny; Asano : 5, text-figs 29–31.
- 1956 *Quinqueloculina lamarckiana* d'Orbigny; Bhatia : 17; pl. 2, figs 10a, b.
- 1956 *Quinqueloculina lamarckiana* d'Orbigny; Marks : 12, 34; pl. 9, figs 19a–c.
- 1956a *Quinqueloculina lamarckiana* d'Orbigny; Asano : 60; pl. 7, figs 17a–c; pl. 8, figs 14a–c, 17a–c; pl. 9, figs 17a, b.
- 1960 *Quinqueloculina lamarckiana* d'Orbigny; Barker (*pars*) : 10; pl. 5, figs 12a–c only (after Brady).
- ? 1960 *Quinqueloculina auberiana* d'Orbigny; Barker : 10; pl. 5, figs 8, 9 (after Brady).
- 1960 *Quinqueloculina lamarckiana* d'Orbigny; Chang : pl. 7, figs 5a–7b.

- 1961 *Quinqueloculina lamarckiana* d'Orbigny; Braga : 56; pl. 5, fig. 3.
 ? 1964 *Quinqueloculina carinata* d'Orbigny; Le Roy : F19; pl. 12, figs 19, 20.
 1969 *Quinqueloculina lamarckiana* d'Orbigny; Resig : 77; pl. 2, fig. 14.
 1970 *Quinqueloculina lamarckiana* d'Orbigny; Kim, Kim & Kim : 154; pl. ix-1, figs 7a-c.

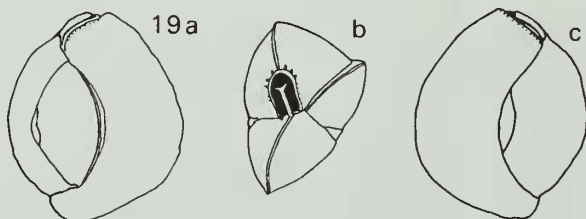
MATERIAL. 110 specimens. NB 9449, 9450.



Figs 18a-d *Quinqueloculina lamarckiana* d'Orbigny. ZF 3813. Front, apertural, rear and edge views. Note characteristic apertural neck protruding above the outline of the penultimate chamber and rounded aperture with short simple tooth. Recent, Pedro Bank, south-west of Jamaica. $\times 60$.

VARIATION. Length 0.25–1.55 mm, breadth 0.17–1.35 mm, thickness 0.13–0.90 mm.

REMARKS. There is much confusion in the literature concerning d'Orbigny's three smooth carinate species, *Q. lamarckiana*, *Q. cuvieriana* and *Q. auberiana*, all of which were originally described from Cuba and adjacent waters.



Figs 19a-c *Quinqueloculina cuvieriana* d'Orbigny. P50074. Front, apertural (see also Pl. 1, fig. 14) and rear views. Sample NB 9450. $\times 35$.

We have been able to examine specimens of *Q. lamarckiana* and *Q. cuvieriana* from the Pedro Bank, south-west of Jamaica, and an example of the former species from this locality, of similar size to that figured by d'Orbigny, is shown in Figs 18a-d. It has the characteristic apertural neck protruding above the outline of the penultimate chamber and a rounded aperture with a short simple tooth. Large specimens from the same sample have an even more produced neck as drawn by Le Calvez & Le Calvez (1958 : pl. 9, fig. 105). In specimens of *Q. cuvieriana*, on the other hand, the aperture is nearly flush and the tooth relatively larger, projecting above the outline of the aperture in larger specimens, when seen in lateral view. Fine striations are often developed in this form (P. Marshall, personal communication), but they can also occur in *Q. lamarckiana*, so this factor may be a variable characteristic in the group as a whole. *Q. auberiana* appears to be a rare species in the Caribbean and is not found in the Pedro Bank samples; it has an aperture like that in *Q. cuvieriana* differing according to d'Orbigny (1839 : 193) in '... les ondulations transversales dont elle est ornée'. We have yet to see an illustrated specimen showing this character and are thus uncertain whether *Q. cuvieriana* and *Q. auberiana* are conspecific or not. If they are, the former name has page-priority. D'Orbigny's type-figures (1839 : pl. 11, figs 19-21 and pl. 12, figs 1-3) are certainly very similar.

The situation was further complicated when Le Calvez & Le Calvez (1958 : 187) introduced *Q. viennensis* for Brady's *Q. cuvieriana* from Japan. They stated that they had examined d'Orbigny's

type-specimen in Paris and found that the two were very different; this is borne out by their photograph of the type (1958: pl. 8, fig. 90). This refigured specimen of *Q. cuvieriana* is, however, most unlike that shown by d'Orbigny in 1839, thus to prevent any confusion we are basing our identification on the original figure.

On this evidence we conclude that *Q. lamarckiana* is quite distinct from *Q. cuvieriana* and that our specimens, Brady's and all those listed in the synonymy should be referred to *Q. cuvieriana*. It is worth noting that this species has almost always been reported as *Q. lamarckiana* although in no case is the produced aperture visible.

Most larger specimens of *Q. cuvieriana* in the Togapi samples have strongly carinate peripheries, but a few are rounded or truncate. Fine longitudinal striations occur on some individuals though the majority of tests are smooth. In large specimens (Figs 19a-c; Pl. 1, fig. 14) the aperture is elongate, though always flush, and the tooth long, straight or Y or T shaped and raised above the rim. In small specimens (Pl. 2, figs 12, 13) the aperture becomes sub-rounded.

DISTRIBUTION. *Fossil*: Upper Miocene of Taiwan (Chang 1960); Miocene and Pliocene of Japan (Asano 1951); Pliocene of Okinawa (? Le Roy 1964); Late Tertiary (? Pliocene) of Siberia and Island, Indonesia and the Ewa Borehole, Hawaii (Le Roy 1941a and Resig 1969, respectively); Plio-Pleistocene (Le Roy 1941b) and Pleistocene (Marks 1956) of Java. *Recent*: Widespread in the West Pacific with reliable records also from India and East Africa.

Quinqueloculina exsculpta (Heron-Allen & Earland)

Pl. 1, figs 11, 12

- 1898 *Miliolina bosciana* (d'Orbigny); Millett: 267; pl. 6, figs 1a, b (*non Q. bosciana* d'Orbigny 1839).
 1898 *Miliolina bosciana* (d'Orbigny) costate var., Millett: 268; pl. 6, fig. 3.
 1915 *Miliolina exsculpta* Heron-Allen & Earland: 567; pl. 42, figs 23-26.
 1923 *Adelosina milleti* Wiesner: 76.
 1959 *Quinqueloculina bosciana* d'Orbigny; Graham & Militante: 43; pl. 5, figs 3a, b (*non* d'Orbigny 1839), = smooth forms.
 1959 *Quinqueloculina poeyana* d'Orbigny; Graham & Militante: 46; pl. 5, figs 16a-c (*non* d'Orbigny 1839), = costate forms.
 1968 *Quinqueloculina bosciana* d'Orbigny; Chiji & Lopez: 109; pl. 8, figs 6a, b.

MATERIAL. 53 specimens. NB 9446, 9447, 9449, 9450.

VARIATION.	<i>Smooth forms</i>	<i>Costate forms</i>
Length	0.23-0.35 mm	0.26-0.50 mm
Width	0.12-0.16 mm	0.13-0.23 mm
Thickness	0.10-0.15 mm	0.11-0.19 mm

REMARKS. Wiesner (1923) erected *Adelosina milleti* for Millett's specimens of *M. bosciana* (d'Orbigny) from the Malay Archipelago. However, study of the original material and Heron-Allen & Earland's collections show that this taxon is itself a junior synonym of *Quinqueloculina exsculpta* (Heron-Allen & Earland), a costate species into which Millett's smooth forms at station 19 intergrade. Millett himself recognized a costate variety of *M. bosciana* at this locality and drew attention to the diversity of surface ornamentation in this species.

Smooth and costate forms of *Q. exsculpta* occur in the present material (NB 9449) and are figured here. They also occur in the Philippines where Graham & Militante (1959) have reported the smooth forms as *Q. bosciana* and the costate forms as *Q. poeyana*.

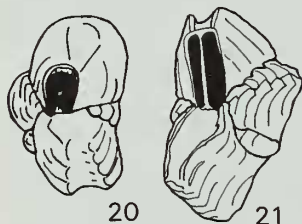
Although the figured syntypes of *Q. exsculpta* are unfortunately damaged, additional material from the Kerimba Archipelago and Vavau Anchorage (Tonga) in the Heron-Allen & Earland type slide collections (192, square 40; 203, square 83; 196, square 17) testifies to the fact that gradation between the smooth and ornamented forms occurs. In view of this it is surprising that Heron-Allen & Earland (1915) did not include Millett's record of *M. bosciana* in the synonymy of their new species.

DISTRIBUTION. Recorded from the Recent of the Kerimba Archipelago, East Africa, the Malay Archipelago, the Philippines, central Japan and Tonga. The Togopi material is believed to constitute the first definite fossil record.

Quinqueloculina parkeri (Brady)

Figs 20–21; Pl. 2, figs 1, 2

- 1858 '*Quinqueloculina* with oblique ridges' Parker : pl. 5, fig. 10 (figures).
 1881 *Miliolina parkeri* Brady : 46 (description).
 1884 *Miliolina parkeri* Brady; Brady : 177; pl. 7, figs 14a–c.
 1915 *Miliolina parkeri* Brady; Heron-Allen & Earland : 574; pl. 43, figs 11, 12.
 1917 *Quinqueloculina parkeri* (Brady) Cushman : 50; pl. 15, figs 3a–c.
 1921 *Quinqueloculina parkeri* (Brady); Cushman : 440; pl. 86, figs 4a–c.
 1924 *Quinqueloculina parkeri* (Brady); Cushman : 59; pl. 22, fig. 3.
 1932 *Quinqueloculina parkeri* (Brady); Cushman : 25; pl. 6, figs 3, 4.
 1954 *Quinqueloculina parkeri* (Brady); Cushman, Todd & Post : 333; pl. 83, fig. 23 only.
 1957 *Quinqueloculina parkeri* (Brady); Todd : 286 (table); pl. 85, figs 13a–14b.
 1958 *Massilina corrugata* Collins : 362; pl. 2, figs 11a–12c.
 1960 *Quinqueloculina parkeri* (Brady); Barker : 14; pl. 7, figs 14a–c (after Brady).
 1961 *Quinqueloculina parkeri* (Brady); Huang : 85; pl. 1, fig. 24.
 1963 *Quinqueloculina parkeri* (Brady); Matsunaga : pl. 28, figs 7a–c.
 1964 *Quinqueloculina parkeri* (Brady); Rocha & Ubaldo : 37; pl. 2, figs 3, 4.
 1965 *Quinqueloculina parkeri* (Brady); Moura : 17; pl. 1, fig. 13.
 1968 *Quinqueloculina parkeri* (Brady); Chiji & Lopez : 110; pl. 9, figs 4a, b.



Figs 20, 21 *Quinqueloculina parkeri* (Brady).
 Contrasting apertural views; compare with further type in Pl. 2, fig. 1. 20, P50241, sample NB 9452. 21, P50242, sample NB 9450. $\times 30$.

MATERIAL. 29 specimens. NB 9447, 9449, 9450, 9452, 9454.

VARIATION. Length 0.30–1.20 mm, width 0.29–1.00 mm, thickness 0.20–0.57 mm.

REMARKS. In the Togopi material, the chamber peripheries of *Quinqueloculina parkeri*, when seen in apertural view, are not only acutely angled (Pl. 2, fig. 1) as in Brady's figured specimen of 1884, but also truncate (Fig. 21) or even rounded (Fig. 20). The ornament is generally well developed on the earlier visible chambers but is often sparse or absent over the last chamber, particularly in the apertural region. Brady's specimens from Honolulu and those of Parker from the Indian Ocean have been examined and show limited variation both in ornamentation and the shape of the chambers when seen aperturally; the chamber peripheries, however, are never as strongly truncated as many in the Togopi samples. Specimens identified by Millett (1898a) as *Q. parkeri* from the Malay Archipelago, on the other hand, are extremely variable, some of the smaller specimens resembling those of Brady while others (e.g. Millett 1898a: pl. 12, figs 4a, b) have crispate ornamentation in place of the regular ridges and furrows and are closer to *Miliolina kerimbatica* Heron-Allen & Earland with which his material has been synonymized (Heron-Allen & Earland 1915 : 514).

Collins (1958), in erecting this new species *Massilina corrugata*, differentiated it from *Q. parkeri* on account of its blunter periphery and because 'the characters of fully developed megalospheric specimens are those of *Massilina*' (1958 : 362). Both his holotype (pl. 2, fig. 11) and paratype (pl. 2, fig. 12) in the BM(NH), however, appear to be quinqueloculine and strongly resemble much of the Togopi material. Clearly a close investigation is needed into variation shown by Brady's species, both fossil and Recent, in the Indo-Pacific.

DISTRIBUTION. *Fossil*: Pliocene of northern Japan (Matsunaga 1963); sub-Recent alluvia of the coastal plain of northern Timor (Rocha & Ubaldo 1964). *Recent*: Originally described by Brady (1881) from Parker's specimens from the 'East Indian Seas', the species has subsequently been widely recorded in the western Pacific from central Japan (Chiji & Lopez 1968) to north-east Australia (Collins 1958). Other records include the Seychelles (Brady 1884), Inhaca Islands (Moura 1965) and the Kerimba Archipelago (Heron-Allen & Earland 1915), all off East Africa.

Quinqueloculina philippinensis Cushman

Pl. 2, figs 3–6

- 1917 *Quinqueloculina reticulata* (d'Orbigny); Cushman (*pars*): 55; pl. 16, fig. 1 only.
 1921 *Quinqueloculina kerimbatica* (Heron-Allen & Earland) var. *philippinensis* Cushman: 438; pl. 89, figs 2, 3.
 1936 *Quinqueloculina kerimbatica* (Heron-Allen & Earland); Keijzer: 113, text-figs 15a–f (*non Miliolina kerimbatica* Heron-Allen & Earland 1915).
 1936 *Quinqueloculina thalmanii* Vroman (*in* Boomgaard & Vroman): 422, text-figs 1–5.
 1937 *Quinqueloculina reticulata chitanii* Yabe & Asano: 114; pl. 17, figs. 8a–c.
 1941b *Quinqueloculina kerimbatica* (Heron-Allen & Earland) var. *philippinensis* Cushman; Le Roy: 112; pl. 1, figs 20–22.
 1959 *Triloculina kerimbatica* (Heron-Allen & Earland) var. *philippinensis* (Cushman); Graham & Militante (*pars*): 55; pl. 8, figs 1–3c only.
 1968 *Quinqueloculina (Miliola) kerimbatica* (Heron-Allen & Earland); Hofker (*pars*): 18; pl. 3, figs 12–15 only.
 1974 *Quinqueloculina philippinensis* Cushman; Ponder (*pars*): 244; pl. 13, figs 22, 23 only.

MATERIAL. 90 specimens. NB 9449, 9450, 9452, 9454.

VARIATION. Length 0.48–1.70 mm, width 0.48–1.16 mm, thickness 0.28–0.85 mm.

REMARKS. At Togopi both generations of this species are highly variable, however a basic growth pattern is common to all; the early chambers are very prominent and the well-developed apertural neck is very characteristic. Ornamentation is a relatively coarse reticulum and there is some degree of ribbing. Some highly reticulate specimens (Pl. 2, figs 5, 6) resemble *Q. reticulata chitanii* Yabe & Asano; other specimens resemble *Q. thalmanii* Vroman. Both we consider synonyms.

Keijzer (1936) and Hofker (1968) regarded Cushman's varieties *philippinensis* and *reticulostrata* superfluous, and used only *Q. kerimbatica* (Heron-Allen & Earland). Furthermore, Hofker stated that specimens resembling var. *reticulostrata* were all megalospheric, whereas those like var. *philippinensis* were microspheric.

We have examined the syntypes of var. *philippinensis* and var. *reticulostrata* from the Philippines and have compared them with the types of *Miliolina kerimbatica* from East Africa. *Q. kerimbatica* var. *reticulostrata* (USNM no. 13488, from Albatross station D 5276) has a pronounced ridged neck, a quinqueloculine test, and ornamentation which is made up of sharp costae with large alveoli set obliquely on the final two chambers. *Q. kerimbatica* var. *philippinensis* (USNM no. 13510 from Albatross station D 5159) comprises adult forms slightly smaller than those of the preceding variety, with a similarly pronounced apertural neck and test ornament of a mainly reticulate pattern developed to a greater or lesser degree as in the Togopi material. Syntypes and topotypes of *M. kerimbatica* in the collections of the BM(NH) show a range of ornament (characteristically contorted ridges and grooves) which agrees well with Heron-Allen & Earland's figures (1915: pl. 43, figs 13–23). The apertural neck is usually not prominent and the aperture is distinctly elongate. The test, which appears triloculine externally, is quinqueloculine in thin section. We are of the opinion that both Cushman's varieties should be separated from Heron-Allen & Earland's species (which seems to be more closely related to *Q. parkeri* (Brady)) and moreover are distinct enough to warrant separate specific status. However, juveniles have little ornament and are difficult to separate. An immature form from Togopi with neither the reticulation of *Q. philippinensis*, nor the curved alveoli of *Q. reticulostrata*, is illustrated here (Pl. 2, fig. 4).

Although Ponder (1974 and personal communication) in his review of the *Q. philippinensis* problem comes to similar conclusions to ourselves, we are still not convinced that *Q. pseudoreticulata* Parr is synonymous with *Q. philippinensis* since in the Togopi samples we cannot see gradation between the two. His pl. 13 shows many morphological types which we do not have. It may be that he has grouped together a number of different reticulate species of *Quinqueloculina*, or that this species is even more variable than the Togopi material suggests.

DISTRIBUTION. *Fossil:* Pliocene (Yabe & Asano 1937), Plio-Pleistocene (Le Roy 1941b) and 'Quaternary' (Vroman 1936) of Java. *Recent:* Found in the western Pacific from the Philippines to north-east Australia.

Quinqueloculina polygona d'Orbigny

Pl. 2, fig. 8

1839 *Quinqueloculina polygona* d'Orbigny: 198; pl. 12, figs 21–23.

1932 *Quinqueloculina polygona* d'Orbigny; Cushman (*pars*): 25; pl. 6, figs 6a–c only.

1951 *Quinqueloculina polygona* d'Orbigny; Asano: 5, text-figs 32–34.

1959 *Quinqueloculina polygona* d'Orbigny; Graham & Militante: 46; pl. 6, figs 1a–c.

1961 *Quinqueloculina polygona* d'Orbigny; Huang: 85; pl. 2, figs 17, 18.

1965 *Quinqueloculina polygona* d'Orbigny; Rocha: 417; pl. 4, figs 4, 5.

MATERIAL. 62 specimens. NB 9447, 9449, 9454.

VARIATION. Length 0.35–0.90 mm, width 0.19–0.36 mm, thickness 0.15–0.43 mm.

REMARKS. Both Parr (1945) and Collins (1958) note that the cool-water species, *Quinqueloculina subpolygona*, first recorded from Victoria, Australia (Parr 1945: 196; pl. 12, figs 2a–c) and subsequently from New South Wales (Albani 1968: 99; pl. 7, figs 12–14), is distinct from *Q. polygona* d'Orbigny. The former appears to have a shorter, more strongly carinate and less regularly built test.

DISTRIBUTION. *Fossil:* Pliocene of Japan (Asano 1951). *Recent:* Although originally described from Cuba and Jamaica (d'Orbigny 1839) its occurrence in the Indo-Pacific is well substantiated by many workers. Records include Fiji (Cushman 1932), the Philippines (Graham & Militante 1959), western Taiwan (Huang 1961) and the Mozambique coast (Rocha 1965).

Quinqueloculina pseudoreticulata Parr

Pl. 2, fig. 9

1884 *Miliolina reticulata* (d'Orbigny); Brady: 177; pl. 9, figs 2a, b, 3 (*non Triloculina reticulata* d'Orbigny, 1826).

Plate 2

Scanning Electron Micrographs

Figs 1, 2 *Quinqueloculina parkeri* (Brady). P50075, P50076. Apertural and side views. Samples NB 9447 and NB 9450 respectively. $\times 60$. (Compare Figs 20–21, p. 26.)

Figs 3–6 *Quinqueloculina philippinensis* Cushman. Fig. 3, P50077. Side view of 'typical specimen'. Sample NB 9449. Fig. 4, P50078. Side view of ? juvenile specimen. Sample NB 9449. Figs 5, 6, P50079, P50080. Side and apertural views of highly reticulate specimens like *Q. reticulata chitanii* Yabe & Asano. Sample NB 9450. All $\times 35$.

Fig. 7 *Quinqueloculina sulcata* d'Orbigny. P50081. Side view. Sample NB 9450. $\times 35$.

Fig. 8 *Quinqueloculina polygona* d'Orbigny. P50082. Side view. Sample NB 9449. $\times 75$.

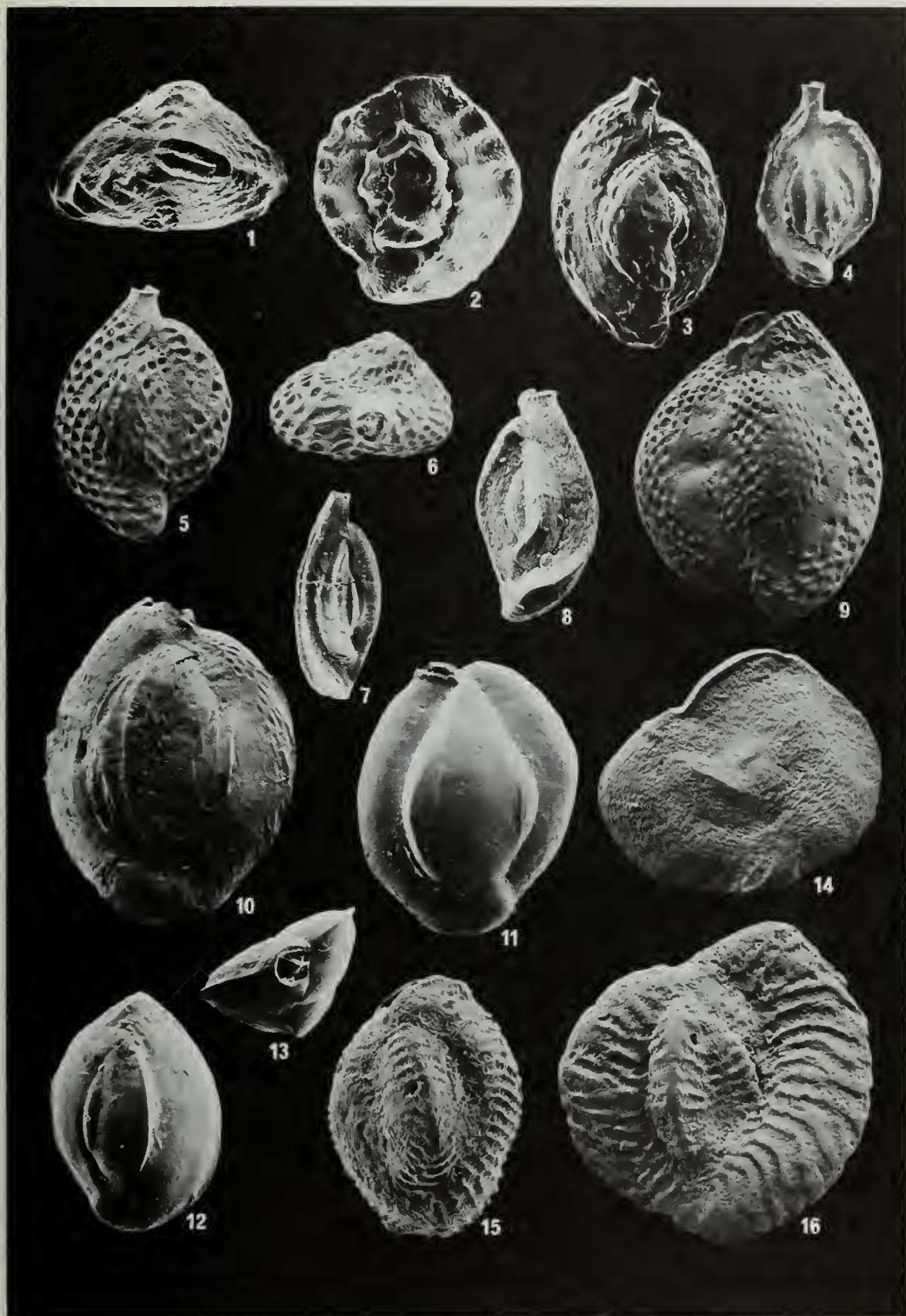
Fig. 9 *Quinqueloculina pseudoreticulata* Parr. P50083. Side view. Sample NB 9450. $\times 35$.

Figs 10, 11 *Quinqueloculina curta* Cushman. P50084, P50085. Side views of specimens with secondary reticulation and poorly-developed carinae respectively. Sample NB 9449. $\times 25$. (See Figs 15, 17, p. 23.)

Figs 12, 13 *Quinqueloculina cuvieriana* d'Orbigny. P50086, P50087. Side and apertural views of small carinate specimens. Sample NB 9449. $\times 75$.

Fig. 14 *Pseudomassilina australis* (Cushman). P50088. Side view. Sample NB 9452. $\times 60$.

Figs 15, 16 *Pseudomassilina medioelata* sp. nov. Fig. 15, P50090. Side view of immature specimen. Paratype, sample NB 9452. Fig. 16, P50089. Side view of adult specimen. Holotype, sample NB 9452. Both $\times 60$. (See Fig. 24, p. 32.)



- 1941 *Quinqueloculina reticulata* (d'Orbigny); Le Roy : 22; pl. 3, figs 1-3.
 1941a *Quinqueloculina reticulata* (d'Orbigny); Le Roy : 71; pl. 5, figs 1, 2.
 1941a *Quinqueloculina reticulata* (d'Orbigny) var. *elongata* Le Roy : 71; pl. 5, figs 13, 14.
 1941 *Quinqueloculina pseudoreticulata* Parr : 305.
 1951 *Quinqueloculina reticulata* (d'Orbigny); Asano : 6, text-figs 35, 36.
 1958 *Quinqueloculina reticulata* (d'Orbigny); Ganapati & Satyavati : pl. 2, fig. 32.
 1960 *Quinqueloculina pseudoreticulata* Parr; Barker : 18; pl. 9, figs. 2a, b, 3 (after Brady).
 1964 *Quinqueloculina reticulata* (d'Orbigny); Le Roy : F19; pl. 12, figs 21, 22.
 1964 *Quinqueloculina pseudoreticulata* Parr; Rocha & Ubaldo : 38; pl. 2, fig. 7.
 1964a *Quinqueloculina pseudoreticulata* Parr; Rocha & Ubaldo : 412; pl. 1, figs 4a, b.
 1964b *Quinqueloculina pseudoreticulata* Parr; Rocha & Ubaldo : 647 (list); pl. 2, figs 3, 4.
 1965 *Quinqueloculina pseudoreticulata* Parr; Moura : 18; pl. 1, fig. 14.
 1967 *Quinqueloculina pseudoreticulata* Parr; Lloyd : 88; pl. 13, figs 5a-c.
 1968 *Quinqueloculina pseudoreticulata* Parr; Albani : 98; pl. 7, figs 18-20.
 1968 *Quinqueloculina reticulata* (d'Orbigny); Chiji & Lopez : 110; pl. 9, figs 5a-c.
 1974 *Quinqueloculina philippinensis* Cushman; Ponder (*pars*) : 244; pl. 13, figs 9, 10, 14, 15, 21, 24 only.

MATERIAL. 37 specimens. NB 9447, 9449, 9450, 9452, 9453, 9454.

VARIATION. Length 0.60-1.43 mm, width 0.35-1.16 mm, thickness 0.25-0.80 mm.

REMARKS. Normally, in the Togopi material, 3 chambers are seen on one side of the test, 4 on the other. Sometimes, however, the ratio is 3 : 3 and occasionally as many as 5 or 6 chambers have been counted on one side. The reticulate ornament is confined predominantly to the peripheral surface of each chamber, as reported by Brady (1884) and Albani (1968), the central part of each face being smooth. In larger specimens the chamber edges are broadly rounded, while in smaller specimens they are more acute.

Examination of the holotype of *Q. pseudoreticulata* and over 70 syntypes from 'Challenger' station 188, south of New Guinea, confirms that the holotype is fully exemplary of the species. Furthermore, no specimen has the test shape, produced apertural neck and coarser ornamentation of *Q. philippinensis* (Cushman). This is in conflict with the findings of Ponder (1974), who states he has evidence of a gradational series. The differences between these two species as seen in the Togopi Formation are illustrated in Pl. 2, figs 3-6, 9.

The differences between *Q. pseudoreticulata* Parr and d'Orbigny's *Triloculina reticulata* from the Mediterranean are given by Parr (1941). Cherif (1973 : pl. 14, fig. 3) has recently illustrated the latter from the Aegean Sea.

DISTRIBUTION. *Fossil*: Miocene of Okinawa, west Pacific (Le Roy 1964) and Wreck Island, north-east Australia (Lloyd 1967); Pliocene of Japan (Asano 1951); Late Tertiary of east Borneo (? Upper Miocene-Pliocene) (Le Roy 1941) and Siberot Island, Indonesia (? Pliocene) (Le Roy 1941a); Sub-Recent alluvia from a raised coastal platform, northern Timor (Rocha & Ubaldo 1964). *Recent*: South of New Guinea (Brady 1884); New South Wales (Albani 1968); central Japan (Chiji & Lopez 1968); west (Rocha & Ubaldo 1964a, b) and east (Ganapati & Satyavati 1958) coasts of India; Mozambique (Moura 1965).

Quinqueloculina sulcata d'Orbigny

Pl. 2, fig. 7

- 1826 *Quinqueloculina sulcata* d'Orbigny : 301, no. 17.
 1900 *Quinqueloculina sulcata* d'Orbigny; Fornasini : 364, text-fig. 9 (d'Orbigny's unpublished figure).
 1932 *Quinqueloculina sulcata* d'Orbigny; Cushman : 28; pl. 7, figs 5-8c.
 1949 *Quinqueloculina sulcata* d'Orbigny; Said : 11; pl. 1, fig. 20.
 1954 *Quinqueloculina sulcata* d'Orbigny; Cushman, Todd & Post : 334; pl. 84, figs 1, 2.
 ? 1956a *Quinqueloculina* sp. Asano : 65; pl. 7, figs 18a-c.
 1968 *Quinqueloculina sulcata* d'Orbigny; Chiji & Lopez : 110; pl. 9, figs 7a, b.

MATERIAL. 25 specimens. NB 9449, 9450, 9452, 9454.

VARIATION. Length 0.15-1.12 mm, width 0.25-0.72 mm, thickness 0.22-0.37 mm.

DISTRIBUTION. Recorded in the Recent of the Red Sea (d'Orbigny 1826, Said 1949), Fiji (Cushman 1932), Marshall Is., west Pacific (Cushman, Todd & Post 1954) and Japan (Chiji & Lopez 1968, ? Asano 1956a). This appears to be the first fossil record.

Quinqueloculina tropicalis Cushman

Figs 22–23; Pl. 1, fig. 13

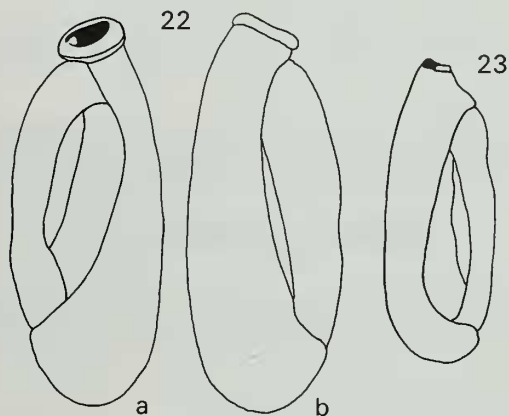
1884 *Miliolina gracilis* (d'Orbigny); Brady : 160; pl. 5, figs 3a–c (*non Triloculina gracilis* d'Orbigny, 1839).

1924 *Quinqueloculina tropicalis* Cushman : 63; pl. 23, figs 9, 10.

1959 *Quinqueloculina laevigata* d'Orbigny; Graham & Militante (*pars*) : 45; pl. 5, figs 13a–c only (*non* d'Orbigny 1826).

1960 *Quinqueloculina tropicalis* Cushman; Barker : 10; pl. 5, figs 3a–c (after Brady).

1969 *Quinqueloculina tropicalis* Cushman; Resig : 78; pl. 2, fig. 5.



Figs 22, 23 *Quinqueloculina tropicalis* Cushman. 22a, b, P50243. Front and rear views. 23, P50244. Small slender form without apertural lip. Sample NB 9449. $\times 95$.

MATERIAL. 60 specimens. NB 9446, 9447, 9448, 9449.

VARIATION. Length 0.25–0.72 mm, width 0.10–0.32 mm, thickness 0.12–0.30 mm.

REMARKS. Cushman (1924) referred the form figured by Brady (1884) to *Q. tropicalis* because 'it is very different from the original *Triloculina gracilis* of d'Orbigny and probably represents a species of the tropical region of the Indo-Pacific'.

The majority of the Togopi specimens have an apertural lip (Figs 22a, b) but a few do not (Fig. 23). The variation is therefore very similar to that illustrated by Cushman. All our material is quinqueloculine.

DISTRIBUTION. This species has previously been described from the Recent of Papua, New Guinea (Brady 1884), the Philippines (Graham & Militante 1959) and Samoa (Cushman 1924) and from the Pleistocene of Ewa Plain, Oahu, Hawaii (Resig 1969).

Genus *PSEUDOMASSILINA* Lacroix, 1938

Type-species: *Massilina australis* Cushman, 1932.

Pseudomassilina australis (Cushman)

Pl. 2, fig. 14; Pl. 10, fig. 2

1884 *Miliolina secans* (d'Orbigny); Brady : 167; pl. 6, figs 1, 2 (*non Quinqueloculina secans* d'Orbigny 1826).

1932 *Massilina australis* Cushman : 32; pl. 8, figs 2a, b.

1936 *Massilina agglutinans* Keijzer : 120, text-figs 18, 19.

1938a *Pseudomassilina australis* (Cushman) Lacroix : 3, text-figs 1a-c.

1960 *Pseudomassilina australis* (Cushman); Barker : 12; pl. 6, figs 1, 2 (after Brady).

MATERIAL. 5 specimens. NB 9452.

VARIATION. Length 0.58–0.84 mm, width 0.62–0.90 mm, thickness 0.17–0.22 mm.

REMARKS. Lack of specimens precludes studies of the test variability and wall structure. However, the latter (Pl. 10, fig. 2) appears to be identical to that described and illustrated by Lacroix (1938a).

We suspect, following comments made by Lacroix (1938a: 9) and Barker (1960: 12), that *Massilina pacificensis* Cushman, 1924 and *M. australis* Cushman [= *Miliolina secans* of Brady] are not only very similar, but also possibly synonymous. We have not seen the types, but if they were found on close study to be conspecific *M. pacificensis* would supplant *M. australis* as the name of the type-species of *Pseudomassilina*.

Keijzer's species, *M. agglutinans*, is regarded as a junior synonym; this author does not appear to have seen either of Cushman's papers cited above. Neither is included in his bibliography (1936: 14).

DISTRIBUTION. Recent of Rarotonga, Cook Is., west Pacific (Cushman 1932), Torres Strait, off north-east Australia (Brady 1884), Cauda Bay, Vietnam and the Gulf of Aqaba, Red Sea (both Lacroix 1938a) and northern Java (Keijzer 1936). This is thought to be the first fossil record.

Pseudomassilina medioelata sp. nov.

Fig. 24; Pl. 2, figs 15, 16; Pl. 10, fig. 1

1959 *Pseudomassilina australis* (Cushman) var. *reticulata* (Heron-Allen & Earland); Graham & Mili-tante : 39; pl. 3, figs 22a-c (non *Massilina secans* d'Orbigny var. *reticulata* Heron-Allen & Earland 1915).



Fig. 24 *Pseudomassilina medioelata* sp. nov.
P50089. Apertural view of holotype (see also
Pl. 2, fig. 16). Sample NB 9452. $\times 60$.

DIAGNOSIS. A *Pseudomassilina* with strong ribs and a very prominent last chamber in the quinqueloculine portion of the test.

NAME. 'Swollen in the middle', from the prominence of the final chamber of quinqueloculine portion of test.

HOLOTYPE. BM(NH) reg. no. P50089, from sample NB 9452.

MATERIAL. 11 specimens. NB 9450, 9452.

DESCRIPTION (Holotype). Test free, initially quinqueloculine, later chambers added planispirally. Early chambers prominent with subacutely-angled chamber peripheries, later planispiral chambers more flattened. Ornament of strong ribs, oblique or at right angles to the long axis of the chambers, tending to recurve towards and extend over the chamber periphery. Surface pitted. Aperture terminal, an elongate slightly sinuous toothless slit occupying the whole face.

DIMENSIONS (Holotype). Length 0.87 mm, breadth 0.82 mm, thickness 0.42 mm.

VARIATION (Paratypes). Length 0.37–1.10 mm, breadth 0.28–0.87 mm, thickness 0.25–0.42 mm.

REMARKS. In our material we have four fully-developed specimens showing the typical flattened planispiral chambers of a *Pseudomassilina* (see holotype, Pl. 2, fig. 16) and seven specimens which

are not fully mature (see paratype, Pl. 2, fig. 15) and exhibit much closer coiled tests. Graham & Militante (1959) illustrate an immature form as *P. australis* var. *reticulata* (Heron-Allen & Earland).

The syntypes of *Massilina secans* var. *reticulata* Heron-Allen & Earland, from Kerimba, have been examined and found not to be conspecific with the Togopi specimens. The Kerimba variety is a typical *P. australis* (compressed and fragile) and has a fine reticulate ornament. Both the Togopi specimens and those of Graham & Militante have stronger, thicker tests and are ornamented by well-developed costae.

The wall-structure has not been fully investigated, but it has the 'granular' appearance (Pl. 10, fig. 1) described by Lacroix (1938).

DISTRIBUTION. Recent of Philippines (Graham & Militante 1959); no previous fossil record.

Genus *PYRGO* Defrance, 1824

Type-species: *Pyrgo laevis* Defrance, 1824.

Pyrgo anomala (Schlumberger)

Pl. 3, fig. 1

1891 *Biloculina anomala* Schlumberger : 569; pl. 11, figs 84–86; pl. 12, fig. 101.

1917 *Biloculina anomala* Schlumberger; Cushman : 79; pl. 32, figs 1a–c.

1921 *Biloculina anomala* Schlumberger; Cushman : 474; pl. 96, figs 1a–c.

1949 *Pyrgo anomala* (Schlumberger) Boomgaart : 67; pl. 5, fig. 15.

1957 *Pyrgo anomala* (Schlumberger); Daleon & Samaniego : 33; pl. 1, fig. 16.

MATERIAL. 10 specimens. NB 9447, 9450.

VARIATION. Length 0.40–0.80 mm, width 0.34–0.68 mm, thickness 0.26–0.55 mm.

DISTRIBUTION. *Fossil*: Miocene of eastern Java (Boomgaart 1949); Neogene, Panay Is., Philippines (Daleon & Samaniego 1957). *Recent*: Hawaiian Islands and the Philippines (Cushman 1917, 1921). Originally described by Schlumberger (1891) from the Mediterranean.

Pyrgo denticulata (Brady)

Pl. 3, fig. 2

1884 *Biloculina ringens* (Lamarck) var. *denticulata* Brady : 143; pl. 3, figs 4a, b, 5.

1915 *Biloculina ringens* (Lamarck) var. *denticulata* Brady; Heron-Allen & Earland : 551; pl. 40, figs. 11–13.

1917 *Biloculina denticulata* (Brady) Cushman; 80; pl. 33, figs 1a–c.

1932 *Pyrgo denticulata* (Brady) Cushman (*pars*) : 62; pl. 14, figs 2a, b, 6a, b only.

1954 *Pyrgo denticulata* (Brady); Cushman, Todd & Post : 340; pl. 85, fig. 22.

1959 *Pyrgo denticulata* (Brady); Graham & Militante (*pars*) : 39; pl. 4, figs 2a–c only.

1960 *Pyrgo denticulata* (Brady); Barker : 6; pl. 3, figs 4a, b, 5 (after Brady).

1961 *Pyrgo denticulata* (Brady); Braga : 87; pl. 8, figs 5, 6.

1969 *Pyrgo denticulata* (Brady); Konda : 89 (table); pl. 7, fig. 5.

MATERIAL. 3 specimens. NB 9449, 9450.

VARIATION. Length 0.57–0.73 mm, width 0.47–0.65 mm, thickness 0.35–0.57 mm.

REMARKS. These three specimens from the Togopi Formation have a maximum of 8 denticles or crenules on the aboral rim; the periphery, when seen in apertural view, is always subacute.

Previous records of this species suggest that it is a somewhat artificial group of denticulate *Pyrgo*, the development of the aperture and the shape of the test in cross section being two characters which seem to vary considerably.

DISTRIBUTION. *Fossil*: Pleistocene of central Japan (Konda 1969). *Recent*: Widespread in the western Pacific (see synonymy) with two records from the east coast of Africa, viz. Kerimba Archipelago (Heron-Allen & Earland 1915) and the Mozambique Coast (Braga 1961).

Genus *TRILOCULINA* d'Orbigny, 1826Type-species: *Miliolites trigonula* Lamarck, 1804.*Triloculina trigonula* (Lamarck)

Pl. 3, fig. 8

- 1804 *Miliolites (trigonula)* Lamarck : 351, no. 3 (description).
 1807 *Miliolites trigonula* Lamarck; Lamarck : 236; pl. 17, fig. 4 (figures).
 1826 *Triloculina trigonula* (Lamarck) d'Orbigny : 299, no. 1; pl. 16, figs 5-9; modèle 93.
 1884 *Miliolina trigonula* (Lamarck) Brady (*pars*) : 164; pl. 3, figs 15a, b, 16 only.
 1917 *Triloculina trigonula* (Lamarck); Cushman : 65; pl. 25, figs 3a, b; text-fig. 31.
 1931 *Triloculina trigonula* (Lamarck); Hada : 85, text-figs 38a, b.
 1932 *Triloculina trigonula* (Lamarck); Cushman : 56; pl. 13, figs 1a, b.
 1936 *Triloculina trigonula* (Lamarck); Keijzer : 103, text-figs 7a-c.
 1941 *Triloculina trigonula* (Lamarck); Le Roy : 22; pl. 3, figs 26-28.
 1949 *Triloculina trigonula* (Lamarck); Said : 19; pl. 2, fig. 12.
 1949 *Triloculina trigonula* (Lamarck); Boomgaart : 66; pl. 5, fig. 13.
 1951 *Triloculina trigonula* (Lamarck); Asano : 17, text-figs 116, 117.
 1954 *Triloculina trigonula* (Lamarck); Cushman, Todd & Post : 340; pl. 85, fig. 18.
 1955 *Triloculina trigonula* (Lamarck); Takayanagi : pl. 1, fig. 14.
 1956a *Triloculina trigonula* (Lamarck); Asano : 75; pl. 8, figs 5a, b.
 1957 *Triloculina trigonula* (Lamarck); Todd : 288 (table); pl. 86, figs 16a, b.
 1960 *Triloculina trigonula* (Lamarck); Chang : 88; pl. 7, figs 14a-15b.
 1960 *Triloculina trigonula* (Lamarck); Barker : 6; pl. 3, figs 15a, b, 16 (after Brady).
 1961 *Triloculina trigonula* (Lamarck); Braga : 75; pl. 7, fig. 1.
 1961 *Triloculina trigonula* (Lamarck); Huang : 86; pl. 2, figs 23, 24.
 1963 *Triloculina trigonula* (Lamarck); Matsunaga : pl. 30, figs 2a, b.
 1964 *Triloculina trigonula* (Lamarck); Bhatia & Bhalla : 79; pl. 1, figs 5a, b.
 1964a *Triloculina* cf. *trigonula* (Lamarck); Rocha & Ubaldo : 413; pl. 5, figs 5a, b.
 1964 *Triloculina trigonula* (Lamarck); Le Roy : F20; pl. 16, figs 30, 31.
 1965 *Triloculina trigonula* (Lamarck); Moura : 26; pl. 3, fig. 4.
 1967 *Triloculina trigonula* (Lamarck); Lloyd : 92; pl. 14, figs 9 (? 8a, b).
 1968 *Triloculina trigonula* (Lamarck); Bhalla : 382; pl. 1, figs 2a, b.
 1968 *Triloculina trigonula* (Lamarck); Chiji : pl. 2, fig. 2.
 1968 *Triloculina trigonula* (Lamarck); Chiji & Lopez : 113; pl. 7, figs 12a, b.
 1969 *Triloculina trigonula* (Lamarck); Konda : 92 (table); pl. 5, figs 4a, b.
 1969 *Triloculina trigonula* (Lamarck); Rao : 592; pl. 3, figs 21a, b.
 1970 *Triloculina trigonula* (Lamarck); Matoba : 62; pl. 3, figs 3a, b.
 1970 *Triloculina trigonula* (Lamarck); Bhalla : 157; pl. 20, figs 4a, b.

MATERIAL. 21 specimens. NB 9447, 9448, 9449, 9452, 9454.

VARIATION. Length 0.28-0.65 mm, width 0.19-0.53 mm, thickness 0.22-0.61 mm.

DISTRIBUTION. *Fossil*: Miocene of Taiwan (Chang 1960), eastern Java (Boomgaart 1949) and Wreck Island, north-east Australia (Lloyd 1967); Late Tertiary (? U. Miocene-Pliocene) of eastern Borneo (Le Roy 1941); Pliocene of Japan (Asano 1951, Matsunaga 1963) and Okinawa, west Pacific (Le Roy 1964); Pleistocene of Japan (Chiji 1968, Konda 1969). Originally described from the Eocene of France (Lamarck 1804, d'Orbigny 1826). *Recent*: A cosmopolitan species frequently found throughout the Indo-Pacific region at the present day.

Triloculina bradyana (Cushman)

Pl. 3, fig. 10

- 1884 *Miliolina fichteliana* (d'Orbigny); Brady : 169; pl. 4, figs 9a-c (*non Triloculina fichteliana* d'Orbigny, 1839).
 1921 *Flintina bradyana* Cushman : 467.
 1932 *Triloculina fichteliana* d'Orbigny; Cushman : 55; pl. 12, figs 6a-c.
 1936 *Triloculina fichteliana* d'Orbigny; Keijzer : 106, text-figs 9a-e.
 1959 *Triloculina fichteliana* d'Orbigny; Graham & Militante : 53; pl. 7, figs 10a-c.

1960 *Flintina bradyana* Cushman; Barker : 8; pl. 4, figs 9a-c (after Brady).

1964 *Flintina bradyana* Cushman; Chang : pl. 2, figs 1a, b.

MATERIAL. 13 specimens. NB 9449, 9452, ? 9453, 9454.

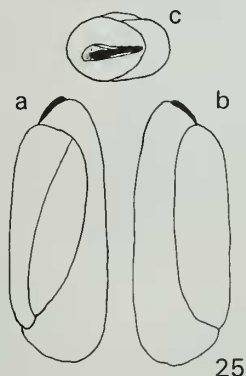
VARIATION. Length 0.61–1.50 mm, width 0.56–1.45 mm, thickness 0.45–1.14 mm.

REMARKS. We have examined specimens of *Triloculina fichteliana* from Jamaica (one of d'Orbigny's original localities) and find that they compare well with the type-figure (d'Orbigny 1839 : pl. 9, figs 8–10) except that they appear to develop a small apertural flap and should therefore be referred to the genus *Miliolinella*.

Cushman (1921) introduced *Flintina bradyana* for Brady's specimens from Japan, and with this we concur, as they, like ours, are not d'Orbigny's species. However, he included large specimens (up to 2 mm in length) from the Philippines which develop three planispiral chambers in the last whorl and a complex tooth: the two main diagnostic features of his new genus *Flintina*.

The Challenger type-material (which Cushman probably never saw) includes specimens up to 1.2 mm in length, all with a narrow simple apertural tooth and no '*Flintina*-like' coil. Since the Togopi material is also entirely triloculine and clearly conspecific with Brady's material we refer it here to *Triloculina*. All forms included in the above synonymy are triloculine.

DISTRIBUTION. *Fossil*: Miocene of Taiwan (Chang 1964). *Recent*: Japan (Brady 1884); Guam (Cushman 1932), Java (Keijzer 1936) and the Philippines (Graham & Militante 1959).



Figs 25a-c *Triloculina* cf. *oblonga* (Montagu). P50245. Specimen with terminal slit aperture in plane of coiling. Front, rear and apertural views. Sample NB 9449. $\times 50$.

Triloculina cf. *oblonga* (Montagu)

Figs 25a-c; Pl. 3, fig. 7

cf. 1803 *Vermiculum oblongum* Montagu : 522; pl. 14, fig. 9.

MATERIAL. 27 specimens. NB 9447, 9449, 9450.

VARIATION. Length 0.24–0.85 mm, width 0.10–0.36 mm, thickness 0.08–0.25 mm.

REMARKS. *Triloculina oblonga*, first described from the Recent of south-west England by Montagu (1803), has subsequently been applied to many different elongate, ovate, smooth miliolids from almost every part of the world. Of the Indo-Pacific records only a few are strictly conspecific with the Togopi specimens and it is for this reason and because of the provenance and imperfectly known nature of the original material that it has been decided to assign this species only tentatively to that of Montagu.

The present specimens are all long and thin and except for a few small quinqueloculine forms, always triloculine. In 13 individuals the aperture is rounded or elongate, never miliolinellid, and the tooth is T-shaped. In the remainder, it is a terminal slit in the plane of coiling (Figs 25a-c), filled or closed by a long narrow tooth. Apertures of this type appear to be rare in this group. They occur, however, in *Triloculina bermudezi* Acosta and *Miliolina deplanata* Rhumbler (Recent

species from the Bahamas and Hawaii, respectively) and in specimens labelled *Miliolina oblonga* (Montagu) from New Caledonia, present in the collections of the British Museum (Natural History). The last-mentioned is almost certainly conspecific with our Togopi specimens.

Triloculina subgranulata Cushman

Pl. 3, fig. 6

1918 *Triloculina subgranulata* Cushman : 290; pl. 96, figs 4a-c.

1959 *Triloculina subgranulata* Cushman; Graham & Militante : 56; pl. 8, figs 11a-c.

MATERIAL. 20 specimens. NB 9447, 9449, 9454.

VARIATION. Length 0.30-0.61 mm, width 0.15-0.41 mm, thickness 0.12-0.32 mm.

REMARKS. All our specimens have the finely granular test indicated by Cushman and Graham & Militante; a few are faintly striate. The aperture in larger specimens is more elongate than in smaller forms where it tends to be rounded.

Possibly also conspecific is a Recent form figured, but not described, by Todd (1957: pl. 86, figs 11a, b) as *Triloculina cuneata*, from Saipan, western Pacific. However, it is almost certainly not the same as Karrer's original species of that name which was described from the Neogene of Roumania in 1867.

DISTRIBUTION. *Recent*: Murray Island off north-east Australia (Cushman 1918) and the Philippines (Graham & Militante 1959). *Fossil*: This appears to be the first fossil record.

Triloculina tricarinata d'Orbigny

Pl. 3, fig. 9

1826 *Triloculina tricarinata* d'Orbigny : 299, no. 7 (description); modèle 94.

1865 *Triloculina tricarinata* d'Orbigny; Parker, Jones & Brady : 34; pl. 1, fig. 8 (after d'Orbigny's model).

1884 *Miliolina tricarinata* (d'Orbigny) Brady : 165; pl. 3, figs 17a, b.

1917 *Triloculina tricarinata* d'Orbigny; Cushman : 66; pl. 25, figs 1, 2; text-fig. 32.

1921 *Triloculina tricarinata* d'Orbigny; Cushman : 454, fig. 37 (includes unfigured var. *convexa*).

1931 *Triloculina tricarinata* d'Orbigny; Hada : 86, text-figs 39a, b.

1932 *Triloculina tricarinata* d'Orbigny; Cushman : 59; pl. 13, figs 3a, b.

1936 *Triloculina tricarinata* d'Orbigny; Keijzer : 103, text-figs 6a, b, d, e.

1941b *Triloculina tricarinata* d'Orbigny; Le Roy : 113; pl. 1, figs 18, 19.

1951 *Triloculina tricarinata* d'Orbigny; Asano : 17, text-figs 114, 115.

1954 *Triloculina tricarinata* d'Orbigny; Cushman, Todd & Post : 340; pl. 85, figs 15, 16.

1956 *Triloculina tricarinata* d'Orbigny; Marks : 35; pl. 10, figs 22a-c.

1956 *Triloculina tricarinata* d'Orbigny; Bhatia : 19; pl. 1, figs 16a, b.

1956a *Triloculina tricarinata* d'Orbigny; Asano : 73; pl. 8, figs 6a, b.

1958 *Triloculina tricarinata* d'Orbigny; Ganapati & Satyavati : 104; pl. 2, figs 38, 39.

1958 *Triloculina tricarinata* d'Orbigny; Sethulekshmi Amma : 8; pl. 1, figs 12, 13.

1959 *Triloculina tricarinata* d'Orbigny; Graham & Militante : 57; pl. 8, figs 14a, b.

1960 *Triloculina tricarinata* d'Orbigny; Barker : 6; pl. 3, figs 17a, b (after Brady).

1961 *Triloculina tricarinata* d'Orbigny; Braga : 77; pl. 7, figs 3, 4.

1963 *Triloculina tricarinata* d'Orbigny; Matsunaga : pl. 30, figs 1a, b.

1964 *Triloculina tricarinata* d'Orbigny; Le Roy : F20; pl. 3, figs 32, 33.

1964a *Triloculina tricarinata* d'Orbigny; Rocha & Ubaldo : 413; pl. 2, figs 6a, b.

1964b *Triloculina tricarinata* d'Orbigny; Rocha & Ubaldo : 647; pl. 2, figs 11, 12.

1965 *Triloculina tricarinata* d'Orbigny; Moura : 26; pl. 3, fig. 2.

1968 *Triloculina tricarinata* d'Orbigny; Antony : 38; pl. 2, figs 13a, b.

1968 *Triloculina tricarinata* d'Orbigny; Bhalla : 381; pl. 1, figs 3a, b.

1968 *Triloculina tricarinata* d'Orbigny; Chiji & Lopez : 113; pl. 7, figs 11a, b.

1968 *Triloculina tricarinata* d'Orbigny; Tewari & Kumar : 42; pl. 14, fig. 5.

1968 *Triloculina tricarinata* d'Orbigny; Hofker : 20; pl. 4, figs 7-10.

1969 *Triloculina tricarinata* d'Orbigny; Rao : 592; pl. 3, fig. 22.

1969 *Triloculina tricarinata* d'Orbigny; Konda : 92 (table); pl. 6, figs 4a, b.

MATERIAL. 152 specimens. NB 9449, 9450, 9452, ? 9453 (rock section).

VARIATION. Length 0.28–0.80 mm, width 0.21–0.59 mm, thickness 0.20–0.65 mm.

REMARKS. In the Togopi material, the chamber sides are rarely straight to gently concave as in d'Orbigny's model, but usually slightly convex. Examination of all the specimens in the Brady Collections labelled *Triloculina tricarinata* d'Orbigny from the Gulf of Suez, northern Red Sea, revealed that only a few are of this type, the others having convex sides. This is also true of Brady's Challenger material (1884). It is therefore probable that the convex-sided forms – named var. *convexa* by Cushman in 1921 – are more common than *T. tricarinata* s.s. in the Indo-Pacific and that there is intergradation in this particular feature. Furthermore, the keeled test, although smooth in the vast majority of specimens, was seen occasionally to be longitudinally costate at the proximal end of the last chamber, similar to *T. tricarinata* d'Orbigny var. *costata* Sethulekshmi Amma (1958: pl. 1, figs 13a, b). Apertures range from triangular to oval in cross section.

DISTRIBUTION. *Fossil*: Miocene (Matsunaga 1963), Pliocene (Asano 1951) and Pleistocene (Konda 1969) of Japan; Miocene and Pliocene of Okinawa, western Pacific (Le Roy 1964); Plio-Pleistocene (Le Roy 1941b) and Pleistocene (Marks 1956) of Java. *Recent*: Ubiquitous in the western Pacific from Japan to the east coast of Australia. In addition it has been reported on a number of occasions from both the west and east coasts of the Indian subcontinent and Sri Lanka (Ceylon). Other records in the region comprise the Red Sea (type-locality of d'Orbigny 1826) and Mozambique (Braga 1961).

Subfamily MILIOLINELLINAE Vella, 1957

Genus *MILIOLINELLA* Wiesner, 1931

Type-species: *Vermiculum subrotundum* Montagu, 1803.

Miliolinella sp.

Pl. 3, fig. 5

MATERIAL. 12 specimens. NB 9447, 9449.

VARIATION.	5 triloculine forms	2 intermediate forms	5 quinqueloculine forms
Length	0.24–0.37 mm	0.28–0.35 mm	0.29–0.45 mm
Width	0.19–0.23 mm	0.18–0.22 mm	0.17–0.26 mm
Thickness	0.16–0.20 mm	0.12–0.19 mm	0.12–0.21 mm

REMARKS. Loeblich & Tappan (1964: C466–8) restricted *Miliolinella* to triloculine forms, as exemplified by the type figure. Haynes (1973: 57), however, showed that in Cardigan Bay, Wales, there is a wide range of coiling within the type-species which includes quinqueloculine forms. We therefore accept a wide concept for the genus as Wiesner had intended, and regard *Scutuloris* (for quinqueloculine forms) as superfluous.

In the Togopi material there is intergradation between triloculine and quinqueloculine forms with two specimens just showing a fourth chamber externally. In addition, the flap-like tooth is variously developed; only in a few specimens does it fully constrict the aperture. Lack of specimens of this smooth species, however, prevents a fuller investigation of its affinities.

Subfamily MILIOLINAE Ehrenberg, 1839

Genus *HAUERINA* d'Orbigny in de la Sagra, 1839

Type-species: *Hauerina compressa* d'Orbigny, 1846.

Hauerina circinata Brady

Figs 26a–c

1881 *Hauerina circinata* Brady: 17 (description).

1884 *Hauerina circinata* Brady; Brady: 191; pl. 11, figs 14–16 (figures).

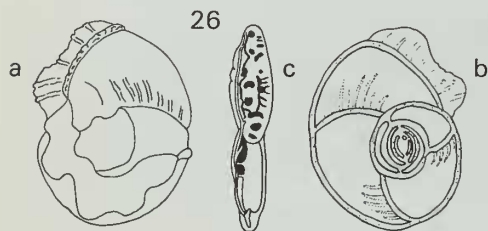
1975 *Hauerina circinata* Brady; Ponder: 8, text-figs 4–24 (q.v. for synonymy).

MATERIAL. 1 specimen (damaged). NB 9449.

DIMENSIONS. Greatest diameter 0.60 mm, thickness 0.10 mm.

REMARKS. *Hauerina circinata*, type-species of the monophyletic genus *Polysegmentina* Cushman (1946: 1), has recently been extensively reviewed by Ponder (1975), based on variable Recent material from north-east Queensland. Ponder concludes that *Polysegmentina* cannot be separated from *Hauerina* either on chamber arrangement or on its possession of retral processes and sutural pores. He finds the retral process-like internal structures are not true retral processes as they do not end blindly at the chamber margins, and the sutural pores do not appear to exist. Ponder also regards *H. diversa* Cushman (1946: 11; pl. 2, figs 16–19) as merely immature specimens of *H. circinata*.

DISTRIBUTION. Probably the first fossil record from the Indo-west Pacific.



Figs 26a–c *Hauerina circinata* Brady. P50251. 26a, side view; 26b, side view in clearing medium viewed by transmitted light; 26c, apertural view. Sample NB 9449. $\times 55$.

Hauerina fragilissima (Brady)

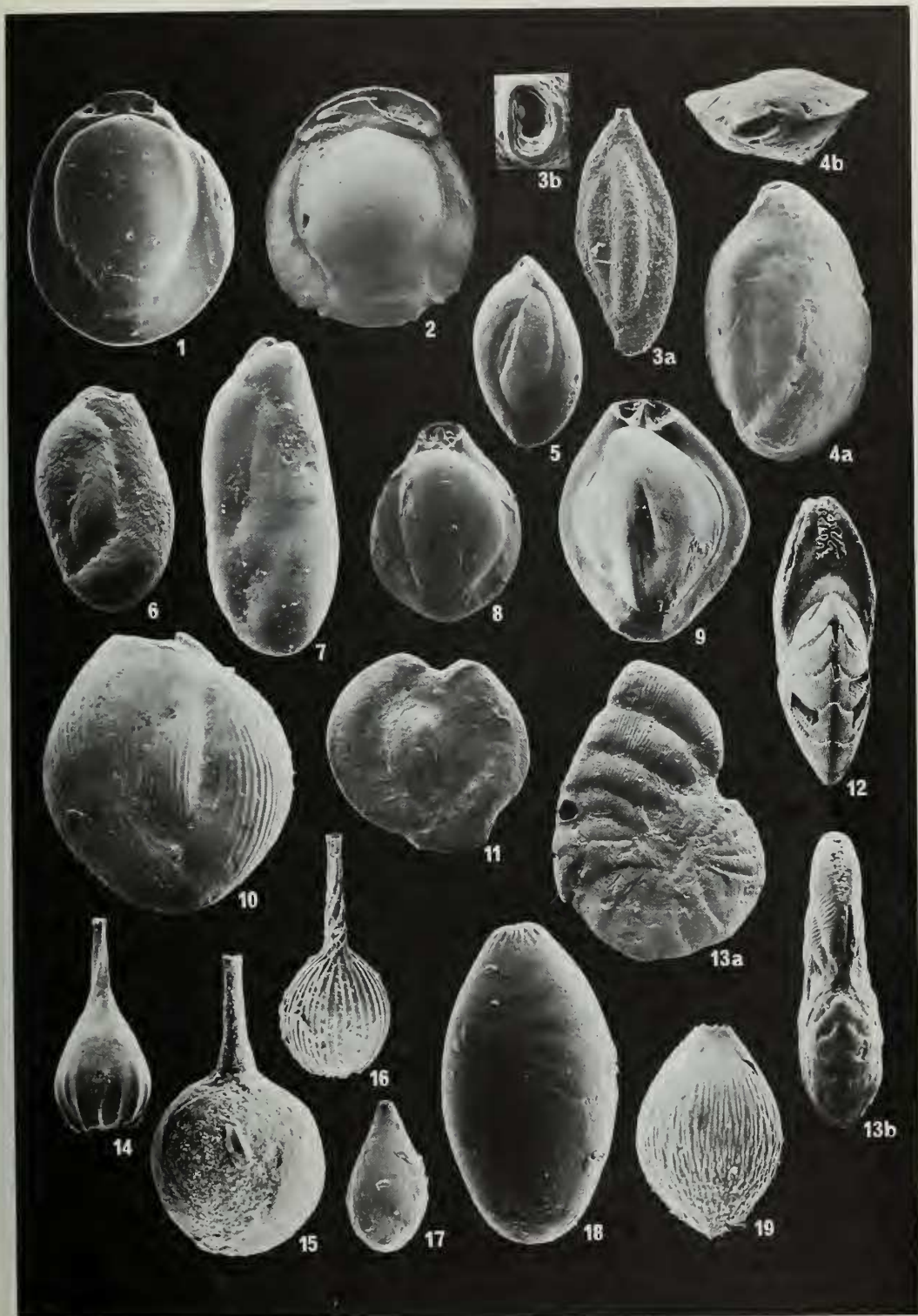
Pl. 3, fig. 11

- 1884 *Spiroloculina fragilissima* Brady: 149; pl. 9, figs 12–14.
 1898b *Hauerina fragilissima* (Brady) Millett: 610; pl. 13, figs 8–10.
 1915 *Hauerina fragilissima* (Brady); Heron-Allen & Earland: 587; pl. 46, figs 1, 2.
 1924 *Hauerina fragilissima* (Brady); Cushman: 68; pl. 25, figs 2, 3.
 1932 *Hauerina fragilissima* (Brady); Cushman: 42; pl. 10, fig. 9.
 1946 *Hauerina fragilissima* (Brady); Cushman: 9; pl. 2, figs 1–6, 8 (after Brady, Millett).
 1951 *Hauerina fragilissima* (Brady); Asano: 11, text-figs 79, 80.
 1958 *Hauerina fragilissima* (Brady); Sethulekshmi Amma: 11; pl. 1, fig. 18.

Plate 3

Scanning Electron Micrographs

- Fig. 1 *Pyrgo anomala* (Schlumberger). P50091. Side view. Sample NB 9450. $\times 70$.
 Fig. 2 *Pyrgo denticulata* (Brady). P50092. Side view. Sample NB 9449. $\times 70$.
 Figs 3a, b ? *Schlumbergerina* sp. P50093. Fig. 3a, side view, $\times 125$; fig. 3b, close-up of edentate siphonate aperture, $\times 500$. Sample NB 9449.
 Figs 4a, b *Edentostomina* cf. *millettii* (Cushman). P50094. Side and apertural views. Sample NB 9452. $\times 30$. (See Fig. 6, p. 17.)
 Fig. 5 *Miliolinella* sp. P50095. Side view. Sample NB 9449. $\times 75$.
 Fig. 6 *Triloculina subgranulata* Cushman. P50096. Side view. Sample NB 9447. $\times 75$.
 Fig. 7 *Triloculina* cf. *oblonga* (Montagu). P50097. Side view. Sample NB 9450. Approx. $\times 60$.
 Fig. 8 *Triloculina trigonula* (Lamarck). P50098. Side view. Sample NB 9449. $\times 75$.
 Fig. 9 *Triloculina tricarinata* d'Orbigny. P50099. Side view. Sample NB 9449. $\times 60$.
 Fig. 10 *Triloculina bradyana* (Cushman). P50100. Side view. Sample NB 9454. $\times 35$.
 Fig. 11 *Hauerina fragilissima* (Brady). P50101. Side view. Sample NB 9450. $\times 60$.
 Figs 12–13b *Dendritina striata* Hofker. Fig. 12, P50102. Apertural (edge) view of typical specimen. Sample NB 9449. Figs 13a, b, P50103. Side and apertural view of specimen showing rectilinear trend. Sample NB 9454. All $\times 30$.
 Fig. 14 *Lagena perlucida* (Montagu). P50104. Side view. Sample NB 9449. $\times 80$.
 Fig. 15 *Lagena flatulenta* Loeblich & Tappan. P50105. Side view. Sample NB 9449. $\times 200$.
 Fig. 16 *Lagena striata* (d'Orbigny). P50106. Side view. Sample NB 9449. $\times 100$.
 Fig. 17 *Lagena laevis* (Montagu). P50107. Side view. Sample NB 9449. $\times 80$.
 Fig. 18 '*Pseudonodosaria*' sp. P50108. Side view. Sample NB 9449. $\times 100$.
 Fig. 19 '*Pseudonodosaria*' *glans* (d'Orbigny). P50109. Side view. Sample NB 9460. $\times 100$.



- 1959 *Hauerina fragilissima* (Brady); Graham & Militante : 35; pl. 3, fig. 9.
 1960 *Hauerina fragilissima* (Brady); Barker : 18; pl. 9, figs 12–14 (after Brady).
 1963 *Hauerina fragilissima* (Brady); Matsunaga : pl. 27, figs 2a, b.
 1964 *Massilina fragilissima* (Brady) Le Roy : F20; pl. 12, fig. 31.
 1968 *Hauerina fragilissima* (Brady); Chiji & Lopez : 107; pl. 10, fig. 9.
 1969 *Hauerina fragilissima* (Brady); Konda : 88 (table); pl. 5, fig. 6.
 1969 *Heterillina fragilissima* (Brady) Resig : 67; pl. 1, fig. 9.
 1975 *Hauerina fragilissima* (Brady); Ponder : 14, text-figs 28–47.

MATERIAL. 8 specimens. NB 9449, 9450.

VARIATION. Length 0.30–0.60 mm, width 0.28–0.55 mm, thickness 0.16–0.18 mm.

REMARKS. The genus *Hauerina* has been reviewed recently by Ponder (1975), based on his study of three Recent species from north Queensland, Australia. He shows that contrary to the definition of Loeblich & Tappan (1964 : C470) the genus shows great variation in the apertural apparatus, chamber arrangement, number of chambers per whorl, involution of the test, inflation of the test and the development of the internal posterior longitudinal ridges.

Our specimens are for the most part similar to Brady's (1884) fig. 14. They have a prominent quinqueloculine early stage with later chambers half a whorl in length. We thus agree with Ponder, who, after studying large numbers of specimens, concluded that only in the later stages of larger individuals are there more than two chambers per whorl.

Because of the lack of variation in our material we are not able to comment on Ponder's conclusion that *Hauerina bradyi* Cushman (= *H. compressa*, *sensu* Brady and Millett) is conspecific with *H. fragilissima* (Ponder 1975 : 18). Our synonymy is therefore confined to records of the latter species only.

DISTRIBUTION. *Fossil*: Pliocene (Asano 1951, Matsunaga 1963) and Pleistocene (Konda 1969) of Japan; Pliocene of Okinawa (Le Roy 1964) and Plio-Pleistocene of Hawaii (Resig 1969). *Recent*: Widespread in the East Indies and western Pacific from central Japan (Chiji & Lopez 1968) to north-west Australia (Ponder 1975). Also known with assurance from the Indian Ocean – Kerimba Archipelago, East Africa (Heron-Allen & Earland 1915) and the Travancore coast of south-west India (Sethulekshmi Amma 1958).

Genus *SCHLUMBERGERINA* Munier-Chalmas, 1882

Type-species: *Schlumbergerina areniphora* Munier-Chalmas, 1882.

Schlumbergerina sp.

Fig. 27

MATERIAL. 1 damaged specimen. NB 9450. Length 1.26 mm.

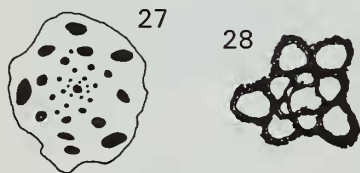


Fig. 27 *Schlumbergerina* sp. P50252. Block section. Sample NB 9450. $\times 36$.

Fig. 28 ? *Schlumbergerina* sp. P50246. Thin section. Sample NB 9449. $\times 126$.

? *Schlumbergerina* sp.

Fig. 28; Pl. 3, figs 3a, b

MATERIAL. 9 specimens. NB 9449.

VARIATION. Length 0.26–0.46 mm, breadth 0.13–0.23 mm, thickness 0.10–0.18 mm.

REMARKS. A very small edentate form. They are juveniles of either *Ammomassilina* or *Schlumbergerina*, probably the latter since the chambers are being added in many planes (Fig. 28).

Family **SORITIDAE** Ehrenberg, 1839Subfamily **PENEROPLINAE** Schultze, 1854Genus **PENEROPLIS** de Montfort, 1808Type-species: *Nautilus planatus* Fichtel & Moll, 1798.*Peneroplis planatus* (Fichtel & Moll) var. *annulata* nov.

Pl. 8, fig. 8

1959 *Peneroplis discoideus* Flint; Graham & Militante: 62; pl. 9, fig. 22 (non *P. pertusus* Forskål var. *discoideus* Flint, 1899).

NAME. Referring to the distinctive annular coiling.

MATERIAL. 2 specimens (1 broken). NB 9452.

DIMENSIONS OF FIGURED SPECIMEN. Maximum diameter 3.30 mm, thickness at periphery 0.25 mm, height of chambers 0.03–0.06 mm, proloculus diameter 0.06 mm.

DESCRIPTION. Test discoidal: a peneroplid coil of $2\frac{1}{4}$ whorls comprising 35–38 undivided chambers, flaring strongly in the later part, followed by up to 10 completely annular chambers. Surface finely striate. Aperture, a single row of pores on the outer face of the last chamber.REMARKS. Both Cole (1965) and Hofker (1971) illustrated and described specimens of *Peneroplis discoideus* from the Caribbean showing various stages of cyclical growth. Cole, however, shows quite convincingly that specimens assigned by various authors not only to this species but also to '*Orbitolites orbitolitoides*' and '*Sorites marginalis*', to name but two, are in fact a single species referable to *Peneroplis proteus* d'Orbigny. All have subepidermal partitions within the chambers, smooth tests, and are demonstrably (Cole 1965: 14) '... a continuous series in which there is progressive thickening and differential deposition of the test wall, and in which the terminal chambers become annular'.The Togopi specimens have a striate ornament and do not develop subepidermal partitions even in the final chambers. They cannot, therefore, be referred to *P. proteus*, but must be considered, if Cole's thesis is accepted, an annular form of the Indo-Pacific striate flabelliform species *Peneroplis planatus* (Fichtel & Moll). Graham & Militante figure a specimen (1959: pl. 9, fig. 12), almost certainly striate, in which cyclical chambers are not fully developed. They consider (1959: 62) it to be a juvenile form of *P. discoideus* (Flint). This is, as far as we are aware, the only other record of the annular form being reported in *P. planatus*.Because this form is rare, and as no typical specimens of *Peneroplis* were found in the Togopi sediments, it has not been possible to study its specific variation. We hesitate, therefore, either to consider it worthy of separate status or, at the other extreme, to be merely conspecific. Instead, for the meantime, we have given it a varietal name, *annulata*.

DISTRIBUTION. The only previous record is a Recent one from north-central Philippines (Graham & Militante 1959).

Genus **DENDRITINA** d'Orbigny, 1826Type-species: *Dendritina arbuscula* d'Orbigny, 1826.*Dendritina striata* Hofker

Pl. 3, figs 12, 13a, b

1951 *Dendritina striata* Hofker: 234, text-figs 12–14.

MATERIAL. 29 specimens. NB 9449, 9452.

VARIATION. Maximum diameter 1.02–2.10 mm, thickness 0.45–0.75 mm. Height of apertural face 0.45–0.90 mm, width of apertural face 0.30–0.50 mm. Number of chambers in last whorl 17–22.

REMARKS. The Togopi specimens closely resemble those described by Hofker (1951). Tests are usually closely coiled, almost involute and, in side view, virtually undistinguishable from Hofker's (1951) text-fig. 12a. The umbilical region is flat or slightly depressed and the sutures heavy with very thick septal walls. The chamber walls, on the other hand, are relatively fragile and often broken. Scanning electron microscopy has confirmed that the longitudinal striae are indeed 'real pits, fused together', as observed by Hofker (1951). Nevertheless, similar striae also occur in related species.

A few specimens tend to uncoil in the adult stage (Pl. 3, figs 13a, b). In most mature specimens the aperture is highly dendritic (Pl. 3, fig. 12), but in a few, including those with some degree of uncoiling, it becomes drawn out and subdivided into separate openings.

DISTRIBUTION. The present fossil record complements Hofker's Recent material from eastern Borneo and the Moluccas.

Subfamily **SORITINAE** Ehrenberg, 1839

Genus **MARGINOPORA** de Blainville, 1830

Type-species: *Marginopora vertebralis* de Blainville, 1830.

Marginopora cf. *vertebralis* de Blainville

Pl. 8, fig. 6

cf. 1830 *Marginopora vertebralis* de Blainville : 337.

cf. 1834 *Marginopora vertebralis* de Blainville; de Blainville : 412; pl. 69, figs 6a-c (*Marginopore vertébral* in plate explanation).

MATERIAL. 2 specimens. NB 9449, 9452.

DIMENSIONS OF FIGURED SPECIMEN. Maximum diameter 1.40 mm, thickness 0.30 mm.

REMARKS. In these pyritized, poorly-preserved specimens, the proloculus is connected to the reniform second chamber by a flexostyle. Annular chambers, at first arcuate but later hexagonal in shape, follow immediately. There are two rows of alternating pores on the periphery. We follow Cole (1954, 1965) in regarding *Amphisorus* as a junior synonym of *Marginopora*.

RANGE. The stratigraphical range of *M. vertebralis* s.l. is Lower Miocene to Recent (Adams 1970 : 119).

Family **ALVEOLINIDAE** Ehrenberg, 1839

Genus **ALVEOLINELLA** Douvillé, 1906

Type-species: *Alveolina quoyi* d'Orbigny, 1826.

Alveolinella quoyi (d'Orbigny)

Pl. 8, fig. 11

1826 *Alveolina quoyi* d'Orbigny : 307; pl. 17, figs 11-13.

1856 *Alveolina boscii* (Defrance); Carpenter : 552; pl. 28, figs 23, 24; pl. 29, figs 4-9 (*non Oryzaria boscii* Defrance, 1820).

1884 *Alveolina boscii* (Defrance); Brady : 222; pl. 17, figs 7-12.

1906 *Alveolinella quoyi* (d'Orbigny) Douvillé : 58.

1908 *Alveolina boscii* (Defrance); Chapman : 151; pl. 2, figs 1-3; pl. 3, figs 4, 5.

1921 *Alveolina boscii* (Defrance); Cushman : 487; pl. 99, figs 2-5.

1930 *Alveolinella quoyi* (d'Orbigny); Hofker : 166; pl. 41, figs 6-8; pl. 63, figs 1-11; pl. 64, figs 1-6.

1933 *Alveolinella quoyi* (d'Orbigny); Cushman : 68; pl. 19, fig. 10.

1954 *Alveolinella quoyi* (d'Orbigny); Todd & Post : 558; pl. 202, figs 5, 8.

1958 *Alveolinella quoyi* (d'Orbigny); Cole : 767; pl. 240, figs 16-25.

1959 *Alveolinella quoyi* (d'Orbigny); Graham & Militante : 65; pl. 10, fig. 12.

1960 *Alveolinella quoyi* (d'Orbigny); Barker : 34; pl. 17, figs 7-12 (after Brady).

1963 *Alveolinella quoyi* (d'Orbigny); Coleman : 10; pl. 1, fig. 1.

1976 *Alveolinella quoyi* (d'Orbigny); Matsumaru : 422; pl. 5, fig. 1.

MATERIAL. 181 specimens. NB 9449, 9452.

VARIATION. Length 4.7 to over 12.0 mm (specimen broken), thickness 1.3–2.5 mm.

DISTRIBUTION. *Fossil*: Neogene (Upper Miocene – ? Tg) of Bikini and Eniwetok Atolls (Todd & Post 1954 and Cole 1958, respectively); Pliocene of the Solomon Islands (Coleman 1963); Pleistocene of the Ryukyu (Nansei Shoto) Islands (Matsumaru 1976). See also Adams (1970: 108, 109). *Recent*: Commonly found today in the shallow shelf seas of the tropical East Indies from the Philippines to north-east Australia.

Family NODOSARIIDAE Ehrenberg, 1838

Subfamily NODOSARIINAE Ehrenberg, 1838

Genus *LAGENA* Walker & Jacob in Kanmacher, 1798

Type-species: *Serpula (Lagena) sulcata* Walker & Jacob, 1798.

Lagena clavata (d'Orbigny)

Pl. 8, fig. 3

- 1846 *Oolina clavata* d'Orbigny : 24; pl. 1, figs 2, 3.
- ? 1865 *Lagena sulcata* (Walker & Jacob) var. *distomapolita* Parker & Jones (*pars*) : 357; pl. 18, fig. 8 only.
- 1949 *Lagena gracillima* (Seguenza); Said : 21; pl. 2, fig. 28 (*non Amphorina gracillima* Seguenza, 1862).
- 1951e *Lagena clavata* (d'Orbigny) Asano : 29, text-fig. 128.
- 1955 *Lagena clavata* (d'Orbigny); Takayanagi : pl. 1, fig. 30.
- ? 1959 *Lagena sulcata* (Walker & Jacob) var. *distomapolita* Parker & Jones; Graham & Militante : 68; pl. 10, fig. 19.
- 1963 *Lagena clavata* (d'Orbigny); Matsunaga : pl. 31, fig. 6.

MATERIAL. 60 specimens. NB 9447, 9449, 9450.

VARIATION. Length 0.45 to over 0.72 mm (broken specimen), maximum breadth 0.11–0.18 mm.

REMARKS. These specimens are typically shaped like Greek amphorae, with the greatest width below mid-point and the apertural end produced into a long neck with a terminal phialine lip. The base of the test has a single spine or a number of smaller spines. Many specimens in the Togopi samples become more elongate and pointed distally, thus resembling those assigned to the variety '*distomapolita*' by Parker & Jones (1865) and Graham & Militante (1959). However, they never develop the aboral tube as in *L. gracillima* (Seguenza), neither do they become as inflated as those figured as *L. clavata* by Cushman (1913 : 9; pl. 2, fig. 2) and Hada (1931 : 103, text-fig. 57).

DISTRIBUTION. *Fossil*: Pliocene of Japan (Asano 1951e, Matsunaga 1963). It was originally described from the Tertiary of the Vienna Basin (d'Orbigny 1846). *Recent*: Records of this species from the Indo-Pacific are few. Certainly conspecific are those from the Red Sea (Said 1949) and Japan (Takayanagi 1955) and possibly those from north-east Australia (Parker & Jones 1865) and the Philippines (Graham & Militante 1959).

Lagena clavata (d'Orbigny) var. *setigera* Millett

Figs 29–37

- 1884 *Lagena laevis* (Montagu) var.; Brady : 455; pl. 56, fig. 30.
- 1901a *Lagena clavata* (d'Orbigny) var. *setigera* Millett : 491; pl. 8, figs 9a, b.
- 1933 *Lagena perlucida* (Montagu); Cushman : 20; pl. 4, figs 6a–8b (*non Vermiculum perlucidum* Montagu, 1803).
- 1950 *Lagena perlucida* (Montagu) var.; Cushman & McCulloch : 343; pl. 46, figs 3a–4b.
- 1951e *Lagena perlucida* (Montagu); Asano : 31, text-figs 137, 138.
- 1959 *Lagena perlucida* (Montagu) var. of Cushman & McCulloch; Graham & Militante : 68; pl. 10, fig. 17.

1960 *Lagena laevis* (Montagu) var.; Barker : 116; pl. 56, fig. 30 (after Brady).

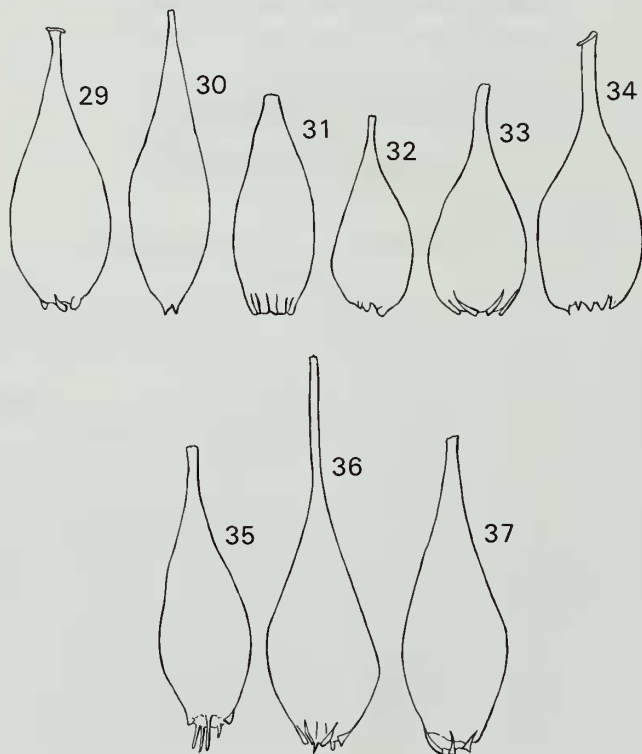
1968 *Lagena perlucida* (Montagu) var. of Cushman & McCulloch; Antony : 55; pl. 3, fig. 22.

1974 *Lagena oceanica* Albani : 37; pl. 1, figs 7, 10, 11.

MATERIAL. 76 specimens. NB 9449, 9450.

VARIATION. Length 0.17–0.42 mm, maximum breadth 0.09–0.13 mm.

REMARKS. This variant differs from *Lagena clavata* (d'Orbigny) in developing fine spines or wings, or both, from a moderately truncate base.



Figs 29–37 *Lagena clavata* (d'Orbigny) var. *setigera* Millett. Showing variation in shape and ornament. 29–34, P50253. Togopi sample NB 9449. $\times 80$. 35–37, ZF3823–ZF3825. Recent, station 5, blue ooze, Malay Archipelago. $\times 120$.

Although Millett's figured syntype cannot be recognized we have examined his residues from the Malay Archipelago and find that this species is common in the blue ooze at station 5 (Durrant 1898). Figs 35–37 show some typical specimens from this locality, while Figs 29–34 illustrate the range of variation in Togopi sample NB 9449. It is clear that the delicately 'setose' form figured by Millett (1901a) is rare and susceptible to damage; usually the rounded end of the test is ornamented by short costae or minute wings as in *Lagena oceanica* Albani.

As Albani (1974) rightly states, this form has often been wrongly referred to *L. perlucida*. He therefore erected a new species, *L. oceanica*, without apparently realizing that a valid taxon already existed.

DISTRIBUTION. *Fossil*: Pliocene of Japan (Asano 1951e). *Recent*: Hong Kong (Brady 1884), the Malay Archipelago (Millett 1901a), Fiji (Cushman 1933), the Philippines (Graham & Militante 1959), south-west coast of India (Antony 1968) and New South Wales, Australia (Albani 1974).

Lagena elongata (Ehrenberg)

Pl. 8, fig. 5

- 1844 *Miliola elongata* Ehrenberg : 274 (description).
 1854 *Miliola elongata* Ehrenberg; Ehrenberg : pl. 25, fig. 1 (figure).
 1884 *Lagena elongata* (Ehrenberg) Brady : 457; pl. 56, fig. 29.
 1901a *Lagena elongata* (Ehrenberg); Millett : 492; pl. 8, fig. 10.
 1913 *Lagena elongata* (Ehrenberg); Cushman : 12; pl. 1, figs 5a, b.
 1938c *Lagena elongata* (Ehrenberg); Asano : 217; pl. 27, fig. 37 only.
 1951e *Lagena elongata* (Ehrenberg); Asano : 30, text-fig. 132.
 1956 *Lagena elongata* (Ehrenberg); Asano : 31; pl. 5, figs 15–17 only.
 1960 *Lagena elongata* (Ehrenberg); Barker : 116; pl. 56, fig. 29 only (after Brady).
 1963 *Lagena elongata* (Ehrenberg); Matsunaga : pl. 31, fig. 7.
 1964 *Lagena elongata* (Ehrenberg); Rocha & Ubaldo : 57; pl. 4, fig. 4.

MATERIAL. 6 specimens, mostly broken. NB 9449, 9452.

VARIATION. Length 0.68–0.91 mm, maximum breadth 0.07–0.10 mm.

REMARKS. The tube-like test of this form appears in the literature to encompass many more shapes than exhibited by the present material which in every case is very similar to the type-figure. The synonymy, therefore, has been restricted to elongate cylindrical forms with nearly parallel sides for a considerable distance. Preservation of the oral and suboral necks is not commonly reported – usually they are broken back – and the apertural phialine lip seen in Pl. 8, fig. 5 is rare even in Recent material.

DISTRIBUTION. *Fossil*: Neogene of Timor (Rocha & Ubaldo 1964), Neogene and Pliocene of Japan (Matsunaga 1963 and Asano 1951e, respectively). The age of Ehrenberg's original material from Kurdistan is not known. *Recent*: Papua (Brady 1884), Malay Archipelago (Millett 1901a) and Japanese waters (Cushman 1913, Asano 1938c and 1956).

Lagena flatulenta Loeblich & Tappan

Pl. 3, fig. 15

- 1953 *Lagena flatulenta* Loeblich & Tappan : 60; pl. 11, figs 9, 10.

MATERIAL. 2 specimens. NB 9449.

DIMENSIONS OF FIGURED SPECIMEN. Length 0.24 mm, width 0.15 mm.

RANGE. Previously recorded only from Recent deposits.

Lagena gracillima (Seguenza)

Pl. 8, fig. 4

- 1862 *Amphorina gracillima* Seguenza : 51; pl. 1, fig. 57.
 1884 *Lagena gracillima* (Seguenza) Brady (*pars*) : 456; pl. 56, figs 25, 26 only.
 1913 *Lagena gracillima* (Seguenza); Cushman : 11; pl. 1, figs 4a, b.
 ? 1937 *Lagena elongata* (Ehrenberg); Yabe & Asano : 118, text-fig. 15 (? *non* Ehrenberg, 1844).
 1960 *Lagena gracillima* (Seguenza); Barker : 116; pl. 56, figs 25, 26 only (after Brady).

MATERIAL. 31 specimens. NB 9449.

VARIATION. Length 0.98 to over 1.72 mm (specimen broken), breadth 0.13–0.25 mm.

REMARKS. Our concept of this species is based on the appearance of our specimens, of which Pl. 8, fig. 4 shows a typical example. Brady's figures (1884 : pl. 56) and a number of other records not included above suggest, however, that there may be greater variation particularly in the shape of the central inflated part of the test.

DISTRIBUTION. *Fossil*: First described from the Upper Miocene of Sicily, the only previous record from the Indo-Pacific appears to be that of Yabe & Asano (1937) from the Pliocene of western Java; this lack of records may be due to the fragility of the test. *Recent*: New Guinea and Kerguelen Island, south Indian Ocean (Brady 1884) and Japan (Cushman 1913).

Lagena laevis (Montagu)

Pl. 3, fig. 17

- 1784 *Serpula* (*Lagena*) *laevis ovalis* Walker & Boys : 3; pl. 1, fig. 9.
 1803 *Vermiculum laeve* Montagu : 524.
 1913 *Lagena laevis* (Montagu) Cushman : 5; pl. 1, figs 3a-c; pl. 38, fig. 5.
 1931 *Lagena laevis* (Montagu); Hada : 102, text-fig. 56.
 1933 *Lagena laevis* (Montagu); Cushman : 19; pl. 4, figs 5a, b.
 1937 *Lagena laevis* (Montagu); Yabe & Asano : 118, text-fig. 7.
 1951e *Lagena laevis* (Montagu); Asano : 31, text-fig. 135 only.
 1956 *Lagena laevis* (Montagu); Asano : 29; pl. 5, figs 6, 7.
 1959 *Lagena laevis* (Montagu); Graham & Militante : 67; pl. 10, figs 15, 16.
 1963 *Lagena laevis* (Montagu); Matsunaga : pl. 31, fig. 10.
 1970 *Lagena laevis* (Montagu); Kim : 106 (table); pl. 1, fig. 9.

MATERIAL. 41 specimens. NB 9449.

VARIATION. Length 0.19–0.45 mm, maximum breadth 0.09–0.25 mm.

REMARKS. We have attempted to assemble a synonymy of the species in the Indo-west Pacific region, based on the variation seen in our material and the appearance of the type-figure. In *Lagena laevis* the unornamented subglobular to inflated ellipsoidal chamber merges slowly into a usually short neck. In *L. flatulenta* Loeblich & Tappan (see Pl. 3, fig. 15 and p. 45), which is often confused with the present species, the long slender neck is quite distinct from the almost globular chamber.

None of the specimens referred by Brady (1884 : pl. 56, figs 7–14, 30) to *L. laevis* resemble the type and are not included.

DISTRIBUTION. *Fossil*: Pliocene of Japan (Asano 1951e, Matsunaga 1963) and Java (Yabe & Asano 1937). *Recent*: Japan (Cushman 1913, Hada 1931 and Asano 1956) and the Korean Yellow Sea (Kim 1970). The species was originally described from the south coast of England (Walker & Boys 1784).

Lagena perlucida (Montagu)

Pl. 3, fig. 14

- 1803 *Vermiculum perlucidum* Montagu : 525; pl. 14, fig. 3.
 1858 *Lagena vulgaris* var. *semistriata* Williamson : 6; pl. 1, fig. 9 (*non L. striata* (Montagu) var. β *semistriata* Williamson, 1848).
 1931 *Lagena sulcata* (Walker & Jacob) var. *interrupta* Williamson; Hada : 110, text-fig. 66 (*non L. striata* (Montagu) var. α *interrupta* Williamson, 1848).
 1963 *Lagena sulcata laevicostata* Cushman & Gray; Matsunaga : pl. 31, fig. 16.
 1971 *Lagena perlucida* (Montagu); Murray : 85; pl. 33, figs 1–3.
 1973 *Lagena perlucida* (Montagu); Haynes : 86; pl. 12, fig. 5.

MATERIAL. 99 specimens. NB 9449, 9450, 9452, 9454, 9460.

VARIATION. Length 0.32–0.52 mm, maximum breadth 0.18–0.23 mm.

REMARKS. The test is subglobular to subtriangular in shape, the greatest width being just above the base. It is ornamented by 10–17 strong longitudinal ribs some of which are long, others short. In many specimens some of the longer ribs pass up into the neck where they either run longitudinally or spirally. At the base of the test the ribs become denticulate.

Murray (1971) and Haynes (1973) have elucidated the morphology of *V. perlucidum* Montagu. It should no longer be confused with *L. semistriata* (p. 47) and *L. clavata* var. *setigera* (p. 43), but records of Montagu's species outside British waters now need verification. The citations of Hada (1931) and Matsunaga (1963) given above are probably conspecific, while the following three species from North America are all very similar to *L. perlucida*:

- 1957a *Lagena saccata* Todd : 231; pl. 28, fig. 12 [from the Neogene of Alaska].
 1946 *Lagena sulcata* Walker & Jacob var. *laevicostata* Cushman & Gray : 68; pl. 12, figs 13, 14 [from the Pliocene of California].

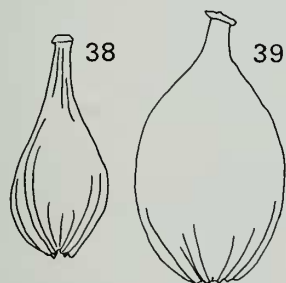
- 1946 *Lagena pliocenica* Cushman & Gray var. *timmsana* Cushman & Gray : 68; pl. 12, figs 15–17 [from the Pliocene of California].

DISTRIBUTION. The records of Hada and Matsunaga are from the Recent and Pliocene of Japan, respectively. Now that this species has been redefined it may prove to be widespread in the Indo-Pacific.

Lagena semistriata Williamson

Figs 38, 39

- 1848 *Lagena striata* (Montagu) var. β *semistriata* Williamson : 14; pl. 1, figs 9, 10.
 1931 *Lagena semistriata* Williamson; Hada : 105, text-fig. 60.
 1933 *Lagena semistriata* Williamson; Cushman : 32; pl. 8, figs 1a, b.
 1937 *Lagena semistriata* Williamson; Yabe & Asano : 118, text-fig. 3.
 1938c *Lagena semistriata* Williamson; Asano (*pars*) : 217; pl. 25, fig. 25; pl. 27, fig. 44; pl. 29, fig. 29 only.
 1941b *Lagena semistriata* Williamson; Le Roy : 114; pl. 3, fig. 22.
 1944 *Lagena semistriata* Williamson; Le Roy : 22; pl. 1, fig. 14.
 1951e *Lagena perlucida* (Montagu); Asano : 31, text-figs 137, 138 (*non Vermiculum perlucidum* Montagu 1803).
 1956 *Lagena cf. perlucida* (Montagu); Asano : 35; pl. 5, fig. 38.
 ? 1958 *Lagena semistriata* Williamson; Sethulekshmi Amma : 57; pl. 2, figs ? 87b, c.
 1973 *Lagena semistriata* Williamson; Haynes : 87; pl. 12, fig. 6; pl. 13, fig. 4.



Figs 38, 39 *Lagena semistriata* Williamson. 38, P40247. Type (b). $\times 100$. 39, P50248. Type (a). $\times 125$. Both from sample NB 9449.

MATERIAL. 44 specimens. NB 9449.

VARIATION. Length 0.20–0.36 mm, maximum breadth 0.09–0.22 mm.

REMARKS. Two forms are recognizable in sample NB 9449. Type (a) comprises subglobular forms with longitudinal striae confined to the basal third of the test (Fig. 39), while type (b) includes more elongate forms with longitudinal striae which are either confined to the basal part of the test or also occur on the neck (Fig. 38). This species differs from *Oolina striata* d'Orbigny in being more pear-shaped, having fewer striae (maximum of 30 against 60), a shorter, stouter neck and a more prominent phialine apertural lip. Following Haynes' (1973) description and excellent illustration of a specimen of *L. semistriata* from Britain we have no hesitation in placing our specimens in this species. Formerly, particularly in the North Atlantic, it has often been confused with *L. perlucida* (Montagu).

DISTRIBUTION. *Fossil:* Miocene of Sumatra (Le Roy 1944); Pliocene of Japan (Asano 1951e) and Pliocene and Plio-Pleistocene of Java (Yabe & Asano 1937 and Le Roy 1941b, respectively). *Recent:* Originally described from the coasts of Britain (Williamson 1848) this species is found widely in the Indo-Pacific at the present day.

Lagena striata (d'Orbigny)

Pl. 3, fig. 16

- 1839b *Oolina striata* d'Orbigny : 21; pl. 5, fig. 12.
 1932 *Lagena striata* (d'Orbigny) Heron-Allen & Earland : 366; pl. 10, figs 10–12.

1937 *Lagena striata* (d'Orbigny); Yabe & Asano : 118, text-fig. 1.

1938c *Lagena striata* (d'Orbigny); Asano : 217; pl. 27, fig. 26; pl. 29, fig. 28.

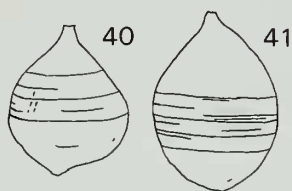
1956 *Lagena striata* (d'Orbigny); Asano : 33; pl. 5, figs 28, 29.

MATERIAL. 99 specimens. NB 9449, 9450, 9452, 9454, 9460.

VARIATION. Length 0.40–0.56 mm, maximum breadth 0.14–0.25 mm.

REMARKS. *Lagena striata* was first described from the Falkland Islands by d'Orbigny (1839b) and was redescribed and better illustrated by Heron-Allen & Earland (1932) from the same area. The globular to subspherical test is ornamented by a great many striae (50–60) some of which run spirally round the neck. There are many incorrect records of *L. striata* from the Indo-Pacific, most of which relate to *L. substriata* Williamson or *L. sulcata* (Walker & Jacob). The latter have recently been reillustrated from the type-area by Murray (1971) and Haynes (1973).

DISTRIBUTION. *Fossil*: Pliocene of Java (Yabe & Asano 1937) and Japan (Asano 1938c). *Recent*: Off Japan (Asano 1956).



Figs 40, 41 *Lagena* sp. Side views. P50249, P50250. Sample NB 9449. $\times 70$.

Lagena sp.
Figs 40, 41

MATERIAL. 18 specimens. NB 9449, 9450.

VARIATION. Length 0.25–0.35 mm, maximum breadth 0.19–0.26 mm.

REMARKS. A globular or subglobular form with a very short neck, ornamented by faint horizontal bands or ridges and sometimes also weak longitudinal striae. Similar forms have been recorded by a number of authors (notably Yabe & Asano 1937 : 118, text-fig. 4, and Le Roy 1941 : 29; pl. 3, fig. 104) as *Lagena globosa* (Montagu), but they appear to lack the horizontal bands. The present specimens are also more inflated than those originally described by Montagu from the British Isles.

Genus *PSEUDONODOSARIA* Boomgaard, 1949

Type-species: *Glandulina discreta* Reuss, 1850.

'*Pseudonodosaria*' *glans* (d'Orbigny)

Fig. 42; Pl. 3, fig. 19

1791 *Nautilus* (*Orthoceras*) *comatus* Batsch (*pars*) : 1, 4; pl. 1, figs 2c, d only.

1826 *Nodosaria* (*Glandulina*) *glans* d'Orbigny : 252, no. 2; modèle 51.

1865 *Nodosaria* (*Glandulina*) *glans* d'Orbigny; Parker, Jones & Brady : 27; pl. 1, fig. 3 (after d'Orbigny's model).

1902 *Nodosaria* (*Glandulina*) *comata* (Batsch); Millett : 512; pl. 11, fig. 2.

1902 *Nodosaria* (*Glandulina*) *laevigata* d'Orbigny; Millett : 509; pl. 11, figs 1a, b (*non* d'Orbigny, 1826).

1921 *Nodosaria* (*Glandulina*) *laevigata* d'Orbigny var. *striatula* Cushman : 186; pl. 33, fig. 12.

1944 *Pseudoglandulina glans* (d'Orbigny) Le Roy : 20; pl. 1, fig. 21.

1959 *Rectoglandulina glans* (d'Orbigny) Graham & Militante : 70; pl. 10, figs 26a–27b.

MATERIAL. 33 specimens. NB 9449, 9450, 9454, 9460.

VARIATION. Length 0.25–0.62 mm, breadth 0.20–0.43 mm.

REMARKS. Batsch (1791) figured two distinct striate species under *Nautilus* (*Orthoceras*) *comatus*. Parker, Jones & Brady (1865), reviewing Batsch's work, applied the name *Nodosaria comata*

only to the elongate form (1791 : pl. 1, figs 2a, b); to the short stout form they assigned d'Orbigny's name *Nodosaria* (*Glandulina*) *glans*, represented by his model 51.

In the Togapi samples this completely uniserial species is generally ornamented by fine longitudinal striae and small spines on the early chambers. However, specimens from the Millett Collection (Station 12, Malay Archipelago – see Durrand 1898) suggest that considerable variation may occur. Some striate specimens are hispid, others not (Millett 1902 : pl. 11, fig. 2), while even other hispid specimens are non-striate (the *Nodosaria* (*Glandulina*) *laevigata* of Millett 1902 : pl. 11, figs 1a, b). The presence of a few non-striate spinose individuals in our material suggests that gradation occurs between hispid and non-hispid forms as well as between striate and smooth forms.

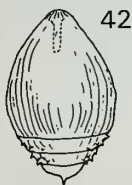


Fig. 42 '*Pseudonodosaria*' *glans* (d'Orbigny). Side view of finely striate hispid specimen showing entosolenian tube. P50254. Sample NB 9449. $\times 75$.

The generic position of the species presents some difficulty. The entosolenian tube (always present in unbroken specimens) suggests that it should be referred to the Glandulinidae, but *Glandulina* is initially biserial (Loeblich & Tappan 1964 : C537); the uniserial *Pseudonodosaria*, on the other hand, does not appear to have an internal tube. If the type-species of *Pseudonodosaria* does not possess an entosolenian tube then a new genus will have to be erected for those forms with uniserial chambers, radial apertures and entosolenian tubes.

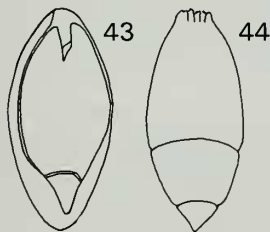
DISTRIBUTION. *Fossil*: Miocene of Sumatra (Le Roy 1944). *Recent*: Malay Archipelago (Millett 1902) and the Philippines (Cushman 1921, Graham & Militante 1959). The species was originally described from the Adriatic shores of Italy (Batsch 1791, d'Orbigny 1826).

'*Pseudonodosaria*' sp.

Figs 43–44; Pl. 3, fig. 18

MATERIAL. 8 specimens. NB 9449, 9450.

VARIATION. Length 0.50–0.85 mm, breadth 0.25–0.45 mm.



Figs 43, 44 '*Pseudonodosaria*' sp. 43, P50255. Acid preparation showing entosolenian tube. Sample NB 9449. $\times 55$. 44, P50256. Side view. Sample NB 9450. $\times 55$.

REMARKS. An elongate smooth form with entosolenian tube. For further remarks on the genus see under '*Pseudonodosaria*' *glans* (d'Orbigny), above.

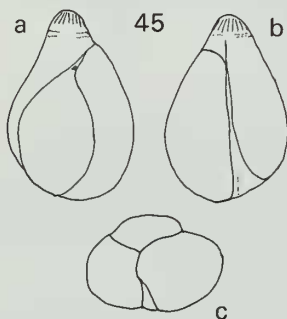
Family **POLYMORPHINIDAE** d'Orbigny, 1839
Subfamily **POLYMORPHININAE** d'Orbigny, 1839
Genus **GUTTULINA** d'Orbigny in de la Sagra, 1839

Type-species: *Polymorphina* (*Guttulina*) *communis* d'Orbigny, 1826.

Guttulina pacifica (Cushman & Ozawa)

Figs 45a-c

- 1884 *Polymorphina elegantissima* Parker & Jones; Brady (*pars*): 566; pl. 72, figs 14, 15 only (*non* Parker & Jones 1865).
 1907 *Polymorphina elegantissima* Parker & Jones; Chapman: 132; pl. 10, fig. 3.
 1928 *Sigmoidella (Sigmoidina) pacifica* Cushman & Ozawa: 19; pl. 2, fig. 13.
 1929 *Sigmoidina pacifica* (Cushman & Ozawa) Cushman & Ozawa: 77; pl. 16, figs 12a-13c.
 1930 *Guttulina (Sigmoidina) pacifica* (Cushman & Ozawa) Cushman & Ozawa: 50; pl. 37, figs 3-5c.
 1951b *Guttulina (Sigmoidina) pacifica* (Cushman & Ozawa); Asano: 5, text-figs 24-26.
 1956 *Guttulina (Sigmoidina) pacifica* (Cushman & Ozawa) var. *ishizakii* Chang: 120; pl. 4, figs 11a-16b.
 1956 *Guttulina (Sigmoidina) pacifica* (Cushman & Ozawa); Chang: 120; pl. 4, figs 17-20.
 1960 *Guttulina (Sigmoidina) pacifica* (Cushman & Ozawa); Barker: 150; pl. 72, figs 14, 15 (after Brady).
 1963 *Guttulina (Sigmoidina) pacifica* (Cushman & Ozawa); Matsunaga: pl. 34, figs 1a, b.
 1964 *Guttulina pacifica* (Cushman & Ozawa); Le Roy: F27; pl. 11, figs 25, 26.



Figs 45a-c *Guttulina pacifica* (Cushman & Ozawa). P50257. Front, rear and basal views. Sample NB 9452. $\times 55$.

MATERIAL. 24 specimens, NB 9452, 9460.

VARIATION. Length 0.30-0.55 mm, breadth 0.22-0.35 mm, thickness 0.22-0.35 mm.

REMARKS. We have dissected a number of specimens and find the basic chamber arrangement to be approximately quinqueloculine, not sigmoidal, with each chamber extending further from the base and strongly overlapping the previous one. Dependent on this degree of overlap the chambers visible on the exterior are either 4:3 or 3:3. Because of the nature of the coiling this species should be referred to *Guttulina*, rather than *Sigmoidella* (see Loeblich & Tappan 1964: C533).

DISTRIBUTION. *Fossil*: Miocene of Okinawa (Le Roy 1964); Miocene and younger sediments of Taiwan (Chang 1956); ? Upper Miocene/Pliocene of Japan (Matsunaga 1963); Pliocene of Japan (Asano 1951b). *Recent*: West Pacific from Japan (Cushman & Ozawa 1929) to south-east Australia (Chapman 1907).

Genus *SIGMOIDELLA* Cushman & Ozawa, 1928

Type-species: *Sigmoidella kagaensis* Cushman & Ozawa, 1928.

Sigmoidella elegantissima (Parker & Jones)

Fig. 46; Pl. 8, fig. 7

- 1865 *Polymorphina elegantissima* Parker & Jones: 438 (table).
 1870 *Polymorphina elegantissima* Parker & Jones; Brady, Parker & Jones (*pars*): 231; pl. 40, figs 15b, c only.
 1884 *Polymorphina elegantissima* Parker & Jones; Brady (*pars*): 566; pl. 72, figs 12, ? 13 only.
 1913 *Polymorphina elegantissima* Parker & Jones; Cushman: 90; pl. 38, figs 1a-c.
 1921 *Polymorphina elegantissima* Parker & Jones; Cushman: 267; pl. 54, figs 1, 2.
 1929 *Sigmoidella elegantissima* (Parker & Jones) Cushman & Ozawa: 76; pl. 16, figs 10, 11a, b.
 1930 *Sigmoidella elegantissima* (Parker & Jones); Cushman & Ozawa: 140; pl. 39, figs 1a-c.

- 1937 *Sigmoidella bakomensis* Yabe & Asano : 102; pl. 18, fig. 8.
 1960 *Sigmoidella elegantissima* (Parker & Jones); Barker : 150; pl. 72, figs 12, ? 13 (after Brady).
 1960 *Sigmoidella bakomensis* Yabe & Asano; Chang : pl. 13, figs 12–13b.
 1965 *Sigmoidella elegantissima* (Parker & Jones); Hedley, Hurdle & Burdett : 20; pl. 6, fig. 20.
 1975 *Sigmoidella* sp. Billman & Kartaadipura : 306; pl. 1, fig. 7.

MATERIAL. 13 specimens. NB 9450, 9452.

VARIATION. Length 0.58–1.35 mm, breadth 0.33–1.00 mm, thickness 0.18–0.65 mm.

REMARKS. The Togopi specimens compare well with the types of *Polymorphina elegantissima* Parker & Jones from Storm Bay, Tasmania, and other specimens from south-east Australia in the Parker Collection. The only exception is that figured by Brady, Parker & Jones (1870 : pl. 40, fig. 15a) which, as indicated by Hedley, Hurdle & Burdett (1965 : 20) is much larger and is poorly preserved. It was this specimen from Melbourne which was considered to belong to *Sigmoidella kagaensis* by Cushman & Ozawa (1930 : 141).



Fig. 46 *Sigmoidella elegantissima* (Parker & Jones). P50183. Block section. Sample NB 9450. $\times 20$.

DISTRIBUTION. *Fossil*: There are no previous illustrations of this species under the name *S. elegantissima*. However, specimens of *Sigmoidella* sp. of Billman & Kartaadipura (1975) from the Pliocene of the Kutei Basin, eastern Borneo, have been verified by us as belonging to this species. We also regard *S. bakomensis* Yabe & Asano as no more than a variant and thus the stratigraphical range probably extends back to the Miocene – Miocene of Java and Taiwan (Yabe & Asano 1937 and Chang 1960, respectively). *Recent*: Common in the warmer latitudes of the western Pacific from the Philippines (e.g. Cushman 1921) to Tasmania (e.g. Cushman 1913) and the North Island of New Zealand (Hedley, Hurdle and Burdett 1965).

Family GLANDULINIDAE Reuss, 1860

Subfamily GLANDULININAE Reuss, 1860

Genus GLANDULINA d'Orbigny in de la Sagra, 1839

Type-species: *Nodosaria* (*Glandulina*) *laevigata* d'Orbigny, 1826.

Glandulina laevigata (d'Orbigny)

Fig. 47

- 1826 *Nodosaria* (*Glandulina*) *laevigata* d'Orbigny : 252, no. 1; pl. 10, figs 1–3.
 1930 *Glandulina laevigata* (d'Orbigny) Cushman & Ozawa : 143; pl. 40, figs 1a, b.
 1933 *Glandulina laevigata* (d'Orbigny); Cushman : 41; pl. 9, figs 14a, b.
 1941 *Glandulina laevigata* (d'Orbigny); Le Roy : 29; pl. 2, fig. 87.
 1941b *Glandulina laevigata* (d'Orbigny); Le Roy : 115; pl. 3, figs 42, 43.
 1944 *Glandulina laevigata* (d'Orbigny); Le Roy : 23; pl. 5, fig. 15.
 1951b *Glandulina nipponica* Asano : 14, text-figs 71–72.
 1959 *Glandulina laevigata* (d'Orbigny); Graham & Militante : 70; pl. 10, figs 29a, b.
 1960 *Glandulina laevigata* (d'Orbigny); Chang : pl. 13, figs 8, 9.
 1963 *Glandulina nipponica* Asano; Matsunga : pl. 33, fig. 7.

MATERIAL. 7 specimens. NB 9449, 9450.

VARIATION. Length 0.24–0.62 mm, breadth 0.14–0.37 mm.

REMARKS. Cushman & Ozawa (1930) reported that topotypes of *G. laevigata* were invariably biserial in the initial portion, not uniserial as originally figured by d'Orbigny. As this character

(Loeblich & Tappan 1964: C537) is critical to the diagnosis of the genus, our synonymy is restricted to records of specimens illustrated or described as initially biserial.

DISTRIBUTION. *Fossil*: Miocene of the Vienna Basin (topotypes; Cushman & Ozawa 1930), Taiwan (Chang 1960) and Sumatra (Le Roy 1944); Late Tertiary (? Upper Miocene/Pliocene) of eastern Borneo and Japan (Le Roy 1941 and Matsunaga 1963, respectively); Pliocene of Japan (Asano 1951*b*) and Plio-Pleistocene of Java (Le Roy 1941*b*). *Recent*: The Philippines (Graham & Militante 1959) and Guam (Cushman 1933).



Fig. 47 *Glandulina laevigata* (d'Orbigny).
P50258. Sample NB 9450. $\times 70$.

Subfamily **OOLININAE** Loeblich & Tappan, 1961

Genus **OOLINA** d'Orbigny, 1839

Type-species: *Oolina laevigata* d'Orbigny, 1839.

Oolina hexagona (Williamson)

Pl. 4, fig. 2

1848 *Entosolenia squamosa* (Montagu) var. γ *hexagona* Williamson: 20; pl. 2, fig. 23.

1960 *Oolina hexagona* (Williamson) Barker: 120; pl. 58, fig. 33 (? 32) (after Brady 1884).

MATERIAL. 2 specimens. NB 9449, 9450.

VARIATION. Length 0.20–0.28 mm, greatest breadth 0.16–0.22 mm.

RANGE. Pliocene (Asano 1951*e*) to Recent.

Oolina squamosa (Montagu)

Pl. 4, fig. 1

1803 *Vermiculum squamosum* Montagu: 5; pl. 14, fig. 2.

1973 *Oolina squamosa* (Montagu) Haynes: 110; pl. 14, fig. 14; pl. 15, figs 4, 5.

MATERIAL. 8 specimens. NB 9450, 9452.

VARIATION. Length 0.20–0.43 mm, greatest breadth 0.17–0.34 mm.

REMARKS. For a reinterpretation of this species see Haynes (1973: 110–111).

RANGE. Miocene (Le Roy 1964) to Recent.

Genus **FISSURINA** Reuss, 1850

Type-species: *Fissurina laevigata* Reuss, 1850.

Fissurina circularis Todd

Pl. 4, fig. 3

1954 *Fissurina circularis* Todd in Cushman, Todd & Post: 351; pl. 87, fig. 27.

MATERIAL. 4 specimens. NB 9449.

VARIATION. Length 0.24–0.27 mm, breadth 0.21–0.27 mm, thickness 0.13–0.15 mm.

RANGE. Uncertain; believed to be the first fossil record from the Indo-west Pacific.

Fissurina radiatomarginata (Parker & Jones)

Fig. 48

1865 *Lagena sulcata* Walker & Jacob var. *marginata* (Montagu) subvar. *radiato-marginata* Parker & Jones : 348, 355; pl. 18, figs 3a, b.

1954 *Fissurina radiato-marginata* (Parker & Jones) Cushman, Todd & Post : 351; pl. 87, fig. 29.

MATERIAL. 2 specimens. NB 9449.

DIMENSIONS. Length 0.30 mm, breadth 0.16 mm, thickness 0.09 mm.

RANGE. Pliocene (Yabe & Asano 1937, Le Roy 1964) to Recent.

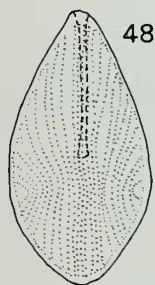


Fig. 48 *Fissurina radiatomarginata* (Parker & Jones). P50259. Sample NB 9449. $\times 125$.

Fissurina spp.

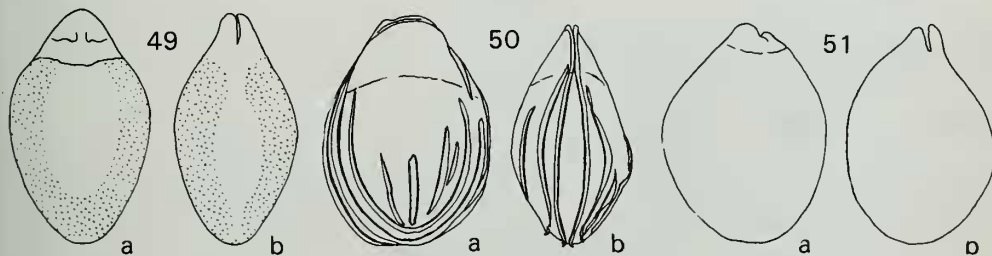
Figs 49–51

Species 1. Figs 49a, b.

MATERIAL. 7 specimens. NB 9450, 9460.

VARIATION. Length 0.27–0.37 mm, greatest breadth 0.21–0.27 mm, thickness 0.18–0.23 mm.

REMARKS. A slightly flattened smooth test; wall transparent except for densely perforate areas forming a horseshoe-shaped opaque pattern on either side of the subacute periphery.



Figs 49a, b *Fissurina* sp. 1. P50260. Side and edge views. Sample NB 9450. $\times 90$.

Figs 50a, b *Fissurina* sp. 2. P50261. Side and edge views. Sample NB 9450. $\times 140$.

Figs 51a, b *Fissurina* sp. 3. P50262. Side and edge views. Sample NB 9450. $\times 80$.

Species 2. Figs 50a, b.

MATERIAL. 5 specimens. NB 9449, 9450, 9452.

VARIATION. Length 0.22–0.25 mm, greatest breadth 0.17–0.20 mm, thickness 0.13–0.14 mm.

REMARKS. Test with 16–18 ribs of unequal length: some are confined to the basal region, some to the middle, while only the principal peripheral ribs extend over the whole length of the shell.

Species 3. Figs 51a, b.

MATERIAL. 7 specimens. NB 9450, 9452.

VARIATION. Length 0.22–0.39 mm, breadth 0.16–0.30 mm, thickness 0.16–0.27 mm.

REMARKS. Test smooth, almost as thick as broad. There is little difference in the density of perforations over the body of the shell, except in the apertural region where it is transparent.

Family **BOLIVINITIDAE** Cushman, 1927

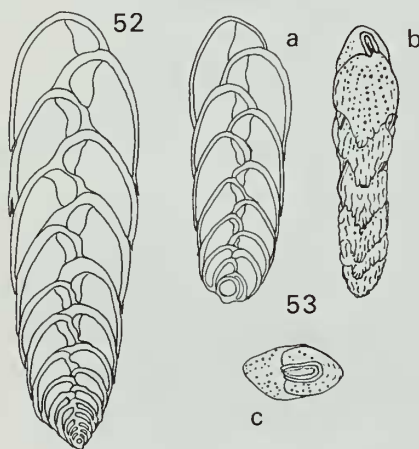
Genus **BOLIVINA** d'Orbigny, 1839

Type-species: *Bolivina plicata* d'Orbigny, 1839.

Bolivina sabahensis sp. nov.

Figs 52–53c; Pl. 4, fig. 4

DIAGNOSIS. A moderately compressed *Bolivina* with a subovate periphery in apertural view. Sides of test sub-parallel, all but the last few chambers ornamented by irregularly developed longitudinal striae which cross and mask the early sutures.



Figs 52–53c *Bolivina sabahensis* sp. nov. 52, P50113. Holotype (microspheric form), side view in clearing medium. See also Pl. 4, fig. 4. 53a–c, P50114. Paratype (megalospheric form). Side view in clearing medium, edge and apertural views. Both from sample NB 9450. $\times 85$.

NAME. Described from Sabah, Malaysia.

HOLOTYPE. BM(NH) reg. no. P50113, from sample NB 9450.

MATERIAL. 41 specimens. NB 9447, 9450.

DESCRIPTION (Holotype: microspheric). Test biserial, calcareous, coarsely perforate, sides hardly tapering except at initial end. Ovate in apertural view with subacute peripheries; thickness virtually constant in edge view. Initial chamber pointed; chambers, 13 in each series, increasing regularly in size and becoming slightly inflated. Ornament of irregular longitudinal striae best developed in early part of the test; on later part restricted to basal portion of chambers where it tends to overlap the sutures. Depressed sutures only seen between last three pairs of chambers. Aperture elongate, sub-terminal, reaching base of apertural face.

DIMENSIONS (Holotype). Length 0.67 mm, breadth 0.20 mm, thickness 0.13 mm.

VARIATION. Size range of paratypes:

	<i>Microspheric</i> (5 specimens)	<i>Megalospheric</i>
Length	0.42–0.67 mm	0.34–0.72 mm
Breadth	0.14–0.20 mm	0.12–0.20 mm
Thickness	0.10–0.15 mm	0.10–0.13 mm

The number of chambers (including the proloculus) varies between 19 and 27 in the microspheric and between 11 and 17 in the megalospheric form.

REMARKS. The microspheric specimens are clearly distinguished by the pointed initial end; megalospheric forms are truncate initially (Fig. 53a). In both generations later sutures tend to become inclined at a greater angle than the earlier sutures. The tooth plate protrudes through the aperture and internally reaches the previous aperture. At low magnifications under the optical microscope the ornament is barely visible and the test appears glossy and highly perforate.

Our specimens have been compared with the following species of similar appearance.

Bolivina bilaensis Le Roy, from the Miocene of Sumatra.

Bolivina tikotoensis Nakamura, from the Pliocene of Taiwan.

Bolivina victoriana Cushman, from the Miocene of Australia.

Bolivina vadescens Cushman, from the Recent of Fiji.

None of them are thought by us to be conspecific. Our material usually differs in apertural aspect and in the number of chambers for a given size; furthermore, none of them appear to possess striate ornament although, as we have stated above, this is often difficult to see in *B. sabahensis*. Of the previously-described striate species of *Bolivina*, the widespread *B. striatula* Cushman is superficially similar but it has only a small number of regular costae on the early chambers and is very compressed in the later part. D. J. Belford has kindly compared our specimens with the many bolivinids in the Neogene of Papua-New Guinea (Belford 1966). He reports that although it is most similar to his own *Brizalina vescistriata* it is not as narrow and elongate and has less distinct striations.

See also Postscript, p. 106.

Genus *BRIZALINA* Costa, 1856

Type-species: *Brizalina aerariensis* Costa, 1856.

Brizalina amygdalaeforme (Brady) *iokiensis* (Asano) Pl. 4, figs 5, 6

1938b *Loxostoma amygdalaeforme iokiense* Asano : 605; pl. 16, figs 3a, b.

1950a *Loxostoma amygdalaeforme iokiense* Asano; Asano : 10, text-fig. 41.

1964 *Loxostomum amygdalaeforme* (Brady) var. *iokiense* Asano; Le Roy : F33; pl. 2, figs 22, 23.

MATERIAL. 21 specimens. NB 9448, 9449, 9450, 9452.

VARIATION. Length 0.30 to more than 0.75 mm (broken specimen), breadth 0.20–0.28 mm, thickness 0.13–0.16 mm. Number of chambers: microspheric form up to 18; megalospheric form 11–15.

REMARKS. This species is referred to *Brizalina* because it lacks the retral chamber processes ('basal chamber lobes' of Belford 1966) and crenulations of *Bolivina*. Moreover, the wall is radial in structure, not granular as in the genus *Loxostomum*.

B. amygdalaeforme iokiensis is characterized by numerous, strong, slightly sinuous, irregularly bifurcating costae; the aperture is subterminal, rarely terminal, with an internal toothplate, bordered by raised thickened lips which are continuations of one of the marginal costae.

Huang (1968) re-examined Nakamura's species *Bolivina formosana*. He concluded that the type-specimen was a juvenile and illustrated other adult, but broken specimens, from the Pliocene Wumeikeng Formation of Taiwan. Unfortunately his illustrations (1968: pl. 3, figs 13, 14; pl. 8, figs 1–6; text-fig. 2) are poor and we cannot determine whether *B. formosana* is conspecific with our material or not, although it appears similar in size and shape. Since Nakamura's original figure (1937: pl. 12, figs 2a, b) may have misled subsequent workers, it is possible that *Loxostomum amygdalaeforme* (Brady) *iokiense* Asano may be a junior synonym. However, as the latter is somewhat better known and has been well illustrated, we prefer to use this name for our specimens.

The raised border to the aperture (giving it a compressed appearance), plus strong costate ornament over the entire test, distinguish it from the Recent Philippines species *Bolivina amygdalaeforme* Brady.

See also Postscript, p. 106.

DISTRIBUTION. *Fossil*: Miocene–Pliocene of Okinawa (Le Roy 1964); Pliocene of Japan (Asano 1938b, 1950a) and possibly Taiwan (Nakamura 1937; Huang 1968). This subspecies does not appear to have been found in post-Pliocene deposits.

Genus *RECTOBOLIVINA* Cushman, 1927

Type-species: *Sagrina bifrons* Brady, 1881. Examination of the type specimens of *Sagrina bifrons* Brady in the British Museum (Natural History) confirms that both generations are biserial initially, later rectilinear and uniserial, with toothplates alternating at 180°. This is in agreement with the diagnosis of *Rectobolivina* by Loeblich & Tappan (1964: C553).

Rectobolivina raphana (Parker & Jones)

Pl. 4, fig. 8

- 1865 *Uvigerina* (*Sagrina*) *raphanus* Parker & Jones : 364; pl. 18, figs 16a, b.
- 1884 *Sagrina raphanus* (Parker & Jones); Brady : 585; pl. 75, figs 21, 22, ? 23 only.
- 1913 *Siphogenerina raphanus* (Parker & Jones) Cushman : 108; pl. 46, figs 1–5.
- 1926 *Siphogenerina raphanus* (Parker & Jones); Cushman : 4; pl. 1, figs 1–4 (1, 2 after Parker & Jones).
- 1931 *Siphogenerina raphanus* (Parker & Jones); Hada : 134, text-figs 91a, b.
- 1942 *Siphogenerina raphana* (Parker & Jones); Cushman : 55; pl. 15, figs 6–9.
- 1949 *Siphogenerina raphana* (Parker & Jones); Said : 34; pl. 3, fig. 26.
- 1950a *Siphogenerina raphanus* (Parker & Jones); Asano : 14, text-figs 56, 57.
- 1954 *Siphogenerina raphana* (Parker & Jones); Cushman, Todd & Post : 356; pl. 88, figs 23, 24.
- 1956 *Siphogenerina raphanus* (Parker & Jones); Bhatia : 21; pl. 1, fig. 6d only.
- 1957 *Siphogenerina raphana* (Parker & Jones); Todd : 290 (table); pl. 89, figs 12a, b.
- 1959 *Siphogenerina raphanus* (Parker & Jones); Graham & Militante : 87; pl. 13, fig. 8.
- 1960 *Siphogenerina raphanus* (Parker & Jones); Barker : 156; pl. 75, figs 21, 22, ? 23 only (after Brady).
- 1962 *Siphogenerina raphanus* (Parker & Jones); Kuwano : text-fig. 8 (table); pl. 22, figs 5a, b.
- 1963 *Siphogenerina raphanus* (Parker & Jones); Matsunaga : pl. 42, figs 8a, b.
- 1964a *Siphogenerina raphanus* (Parker & Jones); Rocha & Ubaldo : 413; pl. 5, fig. 3.
- 1970 *Siphogenerina raphana* (Parker & Jones); Kim : 107 (table); pl. 1, fig. 13.

MATERIAL. 22 specimens. NB 9450.

VARIATION. Length not exceeding 1.2 mm, breadth up to 0.26 mm.

REMARKS. These specimens, which are all megalospheric, bear 12–14 ribs; the chamber shape varies but is usually clearly visible particularly in adult specimens. The initial portion of the shell is biserial. Toothplates in the rectilinear uniserial part alternate through 180°. These specimens are closely similar to the lectotype and paralectotypes (selected by Loeblich & Tappan 1964) which have been examined in a clearing medium and found not to include any completely uniserial form.

DISTRIBUTION. *Fossil*: ? Upper Miocene/Pliocene and Pliocene of Japan (Matsunaga 1963 and Asano 1950a, respectively). *Recent*: Widespread throughout the Indo-Pacific region in Recent sediments.

Rectobolivina raphana (Parker & Jones), var.

MATERIAL. 8 specimens. NB 9449.

VARIATION. Length 0.40–1.05 mm, breadth 0.11–0.24 mm. Number of biserial chambers up to 7, number of uniserial chambers 3–7, longitudinal ribs 7–13.

REMARKS. These specimens differ from *R. raphana* in having a more prominent biserial portion.

Rectobolivina striata (Schwager) var. *curta* (Cushman)

Pl. 4, fig. 9

- 1884 *Sagrina striata* (Schwager); Brady : 584; pl. 75, figs (? 25), 26.
- 1913 *Siphogenerina striata* (Schwager) Cushman : 107; pl. 47, figs 4a, b, 5.

- 1921 *Siphogenerina striata* (Schwager); Cushman : 280; pl. 56, fig. 5.
 1926 *Siphogenerina striata* (Schwager) var. *curta* Cushman : 8; pl. 2, fig. 5.
 1941 *Rectobolivina bifrons* (Brady) var. *striatula* (Cushman); Le Roy : 35; pl. 2, figs 1, 8 (*non* *Siphogenerina bifrons* (Brady) var. *striatula* Cushman, 1917).
 1949 *Siphogenerina striata* (Schwager); Boomgaart : 121; pl. 9, fig. 2.
 ? 1957 *Siphogenerina* 3 (*S. striata* (Schwager)); Daleon & Samaniego : 48; pl. 1, fig. 52.
 1960 *Siphogenerina striata* (Schwager) var. *curta* Cushman; Barker (*pars*) : 156; pl. 75, figs (? 25), 26 (after Brady).
 1961 *Siphogenerina striata* (Schwager); Braga : 148; pl. 15, fig. 21.
 1964 *Rectobolivina bifrons* (Brady) var. *striatula* (Cushman); Le Roy : F34; pl. 3, figs 5, 6.
 1964 *Siphogenerina striata* (Schwager) var. *curta* Cushman; Rocha & Ubaldo : 93; pl. 8, figs 8, 9.

MATERIAL. 11 specimens. NB 9450.

VARIATION. Length 0.40–1.05 mm, breadth 0.11–0.24 mm. Number of biserial chambers usually 7, number of uniserial chambers 3–7, number of ribs 20–35.

REMARKS. Ribbing is variable: it may be strong and continuous over many chambers or weakly developed with breaks at the sutures. There is, however, no gradation to *R. raphana* (Parker & Jones) in our material. All the Togapi specimens are initially biserial with toothplates alternating at 180°, thus justifying the use of the generic name.

The record of Daleon & Samaniego (1957) is questioned owing to poor reproduction of the figure in our copy of their publication.

DISTRIBUTION. *Fossil*: ? Lower Miocene of Java (Boomgaart 1949), Late Tertiary (? Upper Miocene–Lower Pliocene) of eastern Borneo (Le Roy 1941), Neogene of Panay Island, Philippines (Daleon & Samaniego 1957), Miocene–? Pliocene of Okinawa (Le Roy 1964) and Holocene (2 m raised beach) of Timor (Rocha & Ubaldo 1964). *Recent*: North Pacific (Brady 1884, etc.) and Mozambique Coast (Braga 1961).

Family **BULIMINIDAE** Jones, 1875

Subfamily **PAVONININAE** Eimer & Fickert, 1899

Genus **PAVONINA** d'Orbigny, 1826

Type-species: *Pavonina flabelliformis* d'Orbigny, 1826.

Pavonina flabelliformis d'Orbigny

Pl. 4, figs 11a, b

1826 *Pavonina flabelliformis* d'Orbigny : 260; pl. 10, figs 10–12.

MATERIAL. 1 specimen. NB 9450.

DIMENSIONS. Length 0.45 mm, breadth 0.44 mm, thickness 0.10 mm.

REMARKS. A probably immature specimen with few chambers and a pointed initial end. The arrangement of the chambers in the initial portion is not known as it appeared opaque when viewed in clearing media. The apertural face is pustulate, bearing pores of various sizes. For further information on this genus see Cushman (1926: 19–24), Parr (1933) and Hofker (1951b).

RANGE. We believe this to be the first fossil record from Indonesia (Parr 1933).

Genus **CHRYSLIDINELLA** Schubert, 1908

Type-species: *Chrysalidina dimorpha* Brady, 1881.

Chrysalidinella dimorpha (Brady)

Pl. 4, fig. 14

1881 *Chrysalidina dimorpha* Brady : 54.

1884 *Chrysalidina dimorpha* Brady; Brady : 388; pl. 46, figs 20, 21.

MATERIAL. 4 specimens. NB 9450 (? 9449).

VARIATION.

	<i>Microspheric</i>	<i>Megalospheric</i>
Length	0.70–0.94 mm	0.52–0.65 mm
Width	0.30–0.52 mm	0.31–0.34 mm

RANGE. Pliocene (Yabe & Asano 1937) to Recent.

Genus *REUSSELLA* Galloway, 1933

Type-species: *Verneuilina spinulosa* Reuss, 1850.

Reussella sp.

Pl. 4, fig. 13

MATERIAL. 6 specimens. NB 9449, 9450, 9452.

VARIATION. Length 0.28–0.44 mm, breadth 0.21–0.28 mm. Number of chambers 10–14.

REMARKS. Closely resembles *Fijiella* (*Reussella*) *simplex* (Cushman) in shape but possessing a toothplate and a single semilunar instead of a cribrate aperture. Our specimens may be compared with *Verneuilina spinulosa* Reuss (Brady 1884 : 384; pl. 47, figs 1a, b only), *Ruessella* sp. C (Todd & Post 1954 : 559; pl. 199, fig. 11) and *Reussella simplex* Cushman (Todd 1957 : pl. 89, figs 23a, b).

Family UVIGERINIDAE Haeckel, 1894

Genus *SIPHGENERINA* Schlumberger in Milne-Edwards, 1882

Type-species: *Siphogenerina costata* Schlumberger, 1883.

Siphogenerina sp.

Pl. 4, fig. 7

MATERIAL. 3 specimens. NB 9450.

VARIATION. Length 0.50–0.60 mm, width (uniserial portion) 0.15–0.20 mm, (biserial portion) 0.17–0.21 mm. Number of chambers in uniserial and biserial portions respectively 2–3 and ? 8–10.

REMARKS. Examination in a clearing medium appeared to show toothplates set at 120° apart, thus suggesting *Siphogenerina* rather than *Rectobolivina*. The early part of the test is somewhat obscured by pyrite.

Genus *SIPHOUVIGERINA* Parr, 1950

Type-species: *Uvigerina porrecta* Brady var. *fimbriata* Sidebottom, 1918.

Siphouvigerina proboscidea (Schwager) var. *vadescens* (Cushman)

Pl. 4, fig. 10

1933a *Uvigerina proboscidea* Schwager var. *vadescens* Cushman : 85; pl. 8, figs 14, 15.

1942 *Uvigerina proboscidea* Schwager var. *vadescens* Cushman; Cushman : 50; pl. 14, figs 5–9.

1948 *Uvigerina proboscidea* Schwager var. *vadescens* Cushman; Todd in Cushman & McCulloch : 268; pl. 34, fig. 5.

1962 *Uvigerina proboscidea vadescens* Cushman; Kuwano : text-fig. 8 (table); pl. 24, fig. 9.

1964 *Uvigerina proboscidea vadescens* Cushman; Ishiwada : 41; pl. 5, fig. 78.

1964 *Uvigerina proboscidea* Schwager var. *vadescens* Cushman; Le Roy : F35; pl. 3, fig. 38.

1965 *Uvigerina vadescens* Cushman; Aoki : 57; pl. 7, figs 9, 10.

MATERIAL. 17 specimens. NB 9449, 9450, 9452, 9460.

VARIATION. Length 0.25–0.48 mm, breadth 0.15–0.18 mm.

REMARKS. This species has been transferred to *Siphouvigerina* since in many adult specimens the later chambers become biserial or even uniserial, and the simple toothplate is entirely devoid of a

wing. Cushman differentiated his variety from Schwager's species by its smaller size, more slender form and elongate apertural neck. Examination of topotype specimens of *U. proboscidea* from Car Nicobar, identified by Dr M. S. Srinivasan and deposited in the British Museum (Natural History), has confirmed Cushman's varietal diagnosis.

In 1965, Aoki accorded specific rank to this variety without any explanation.

DISTRIBUTION. *Fossil*: Miocene-Pliocene of Okinawa (Le Roy 1964), Plio-Pleistocene of Japan (Aoki 1965). *Recent*: Guam (Cushman 1933a), Fiji (Cushman 1942), Japan (Kuwano 1962, Ishiwada 1964) and 'various tropical localities' (figured specimen locality not specified – Todd in Cushman & McCulloch 1948).

Family **DISCORBIDAE** Ehrenberg, 1838

Subfamily **DISCORBINAE** Ehrenberg, 1838

Genus **DISCORBIS** Lamarck, 1804

Type-species: *Discorbites vesicularis* Lamarck, 1804.

Discorbis cf. *dimidiatus* (Parker & Jones)

Pl. 4, fig. 12

cf. 1862 *Discorbina dimidiata* Parker & Jones : 201, text-fig. 32b.

cf. 1967 *Discorbis dimidiatus* (Parker & Jones); Hedley, Hurdle & Burdett : 33; pl. 1, fig. 4; pl. 10, figs 1–3; text-figs 28–43.

MATERIAL. 10 specimens. NB 9447, 9449.

VARIATION. Length 0.28–0.60 mm, breadth 0.21–0.25 mm, thickness 0.15–0.29 mm. Number of chambers in first whorl 5, in second 5–7 and in final whorl 4–7.

REMARKS. Hedley, Hurdle & Burdett (1967), in their extensive review of *Discorbina dimidiata* Parker & Jones, concluded that it was specifically distinct from the Eocene *Discorbites vesicularis* Lamarck. Furthermore, they considered the genus *Lamellodiscorbis* (type *D. dimidiata*) to be superfluous.

Our small number of immature poorly-preserved specimens are tentatively referred to *Discorbis dimidiatus*, based on the evidence of intraspecific variability illustrated by Hedley *et al.* from Australian and New Zealand Recent material.

Genus **GAVELINOPSIS** Hofker, 1951

Type-species: *Discorbina praegeri* Heron-Allen & Earland, 1913.

Gavelinopsis sp.

Pl. 4, figs 18a, b

MATERIAL. 3 complete and 8 broken specimens. NB 9447, 9449.

VARIATION. Length 0.22–0.27 mm, breadth 0.20–0.25 mm, thickness 0.09–0.14 mm. Number of chambers in first, second and final whorls 5–6, 6–8 and 6–7 respectively.

REMARKS. Placed in *Gavelinopsis* by virtue of its small umbilical plug (Loeblich & Tappan 1964: C578). It must be noted, however, that the validity of the genus is questioned by Haynes (1973: 161).

Our poorly-preserved trochospiral specimens with coarse perforations on the spiral side are similar to *Discorbina praegeri* Heron-Allen & Earland and, except for the presence of a plug, to *Discorbis laddi* Kleinpell.

Genus **ROSALINA** d'Orbigny, 1826

Type-species: *Rosalina globularis* d'Orbigny, 1826.

Rosalina bradyi (Cushman)

Pl. 4, figs 15, 16

- 1884 *Discorbina globularis* (d'Orbigny); Brady : 643; pl. 86, figs 8a-c only (*non Rosalina globularis* d'Orbigny, 1826).
- 1915 *Discorbina globularis* (d'Orbigny); Heron-Allen & Earland : 694; pl. 51, figs 36-39.
- 1915 *Discorbis globularis* (d'Orbigny) var. *bradyi* Cushman : 12; pl. 8, figs 1a-c.
- 1933a *Discorbis opima* Cushman : 88; pl. 9, figs 3a-c.
- 1933a *Discorbis micens* Cushman : 89; pl. 9, figs 5a-c.
- 1951d *Discopulvinulina bradyi* (Cushman) Asano : 4, text-figs 25, 26.
- 1954 *Discorbis globularis* (d'Orbigny); Klempell : 56; pl. 5, figs 1a-c.
- 1954 *Discorbis micens* Cushman; Cushman, Todd & Post : 358; pl. 89, figs 8, 9.
- 1954 *Discorbis opima* Cushman; Cushman, Todd & Post : 358; pl. 89, figs 10, 11.
- 1957 *Discorbis micens* Cushman; Todd : 290 (table); pl. 90, figs 7a-c.
- 1957 *Discorbis opima* Cushman; Todd : 290 (table); pl. 90, figs 11a-c.
- 1959 *Rosalina globularis* d'Orbigny; Graham & Militante : 97; pl. 14, figs 12a-c.
- 1960 *Rosalina bradyi* (Cushman) Barker : 178; pl. 86, figs 8a-c (after Brady).
- 1967 *Rosalina bradyi* (Cushman); Hedley, Hurdle & Burdett : 42; pl. 1, fig. 3; pl. 11, figs 2a-c; text-figs 50-55.
- 1968 *Rosalina bradyi* (Cushman); Albani : 109; pl. 9, figs 1, 2, 5, 6.
- 1970 *Rosalina bradyi* (Cushman); Matoba : 60; pl. 4, figs 8a-c.

MATERIAL. 11 specimens. NB 9447, 9449.

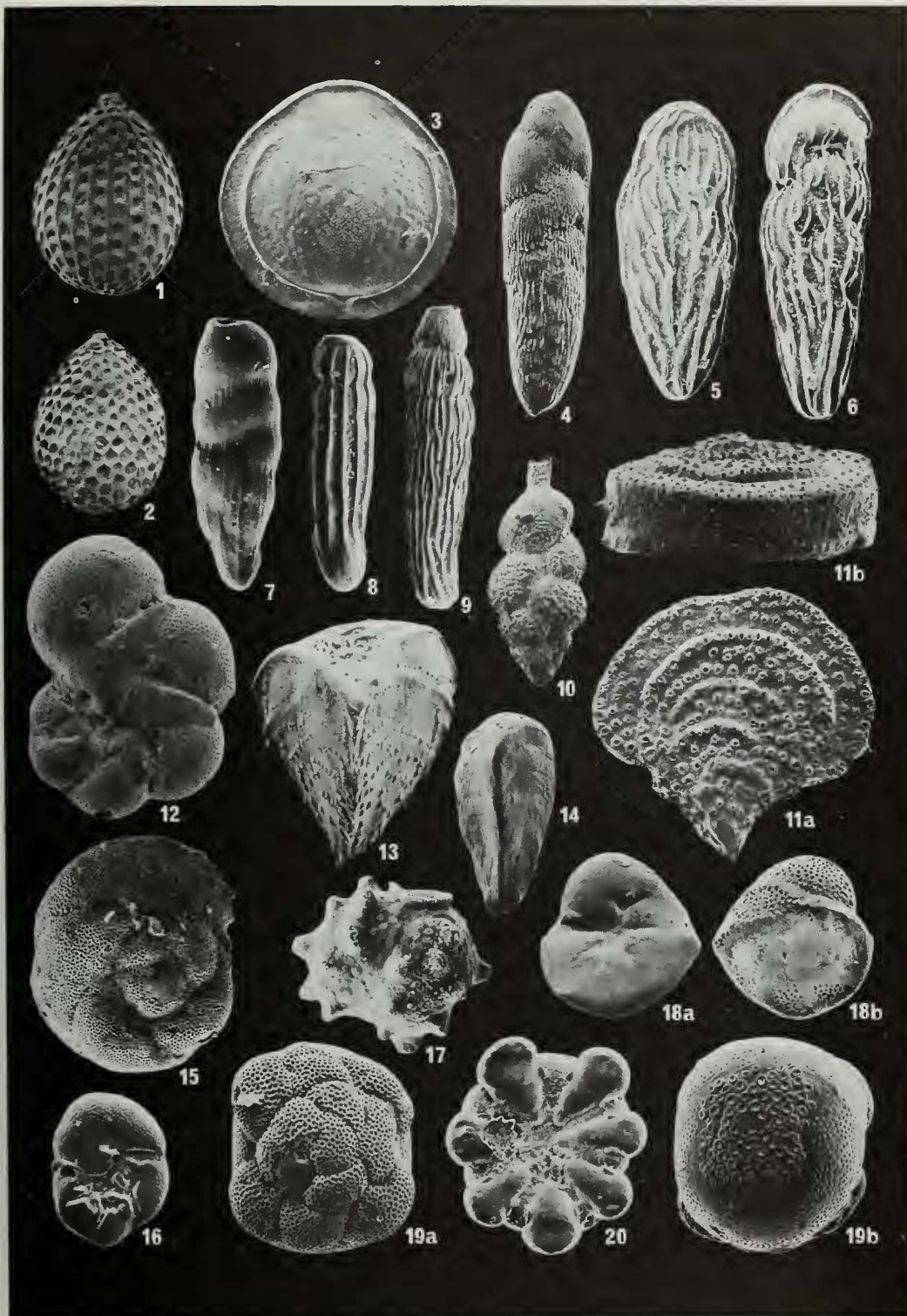
VARIATION. Maximum diameter 0.25-0.55 mm, thickness 0.10-0.27 mm. Numbers of chambers in first whorl 5-7, in second 5-9 and in final whorl 4-5.

REMARKS. The taxonomic position and intraspecific variation of this species have been discussed in some detail by Hedley, Hurdle & Burdett (1967).

Plate 4

Scanning Electron Micrographs

- Fig. 1 *Oolina squamosa* (Montagu). P50110. Side view. Sample NB 9452. $\times 100$.
- Fig. 2 *Oolina hexagona* (Williamson). P50111. Side view. Sample NB 9450. $\times 100$.
- Fig. 3 *Fissurina circularis* Todd. P50112. Side view. Sample NB 9449. $\times 150$.
- Fig. 4 *Bolivina sabahensis* sp. nov. P50113. Side view of holotype (microspheric form). Sample NB 9450. $\times 75$. (See Fig. 52, p. 54.)
- Figs 5, 6 *Brizalina amygdalaeformis* (Brady) *iokiensis* (Asano). P50115, P50116. Side views of megalospheric and microspheric forms. Sample NB 9450. $\times 75$.
- Fig. 7 *Siphogenerina* sp. P50117. Side view. Sample NB 9450. $\times 70$.
- Fig. 8 *Rectobolivina raphana* (Parker & Jones). P50118. Side view. Sample NB 9450. Approx. $\times 50$.
- Fig. 9 *Rectobolivina striata* (Schwager) var. *curta* (Cushman). P50119. Side view. Sample NB 9450. Approx. $\times 50$.
- Fig. 10 *Siphonigerina proboscidea* (Schwager) var. *vadescens* (Cushman). P50120. Side view. Sample NB 9450. $\times 100$.
- Figs 11a, b *Pavonina flabelliformis* d'Orbigny. P50121. Side and apertural views. Sample NB 9450. $\times 100$.
- Fig. 12 *Discorbis* cf. *dimidiatus* (Parker & Jones). P50122. Ventral (umbilical) view. Sample NB 9449. $\times 75$.
- Fig. 13 *Reussella* sp. P50123. Side view. Sample NB 9449. $\times 100$.
- Fig. 14 *Chrysalidinella dimorpha* (Brady). P50124. Side view. Sample NB 9450. $\times 50$.
- Figs 15, 16 *Rosalina bradyi* (Cushman). P50125, P50126. Dorsal and ventral views. Sample NB 9447. Both specimens $\times 75$.
- Fig. 17 *Siphoninoides echinatus* (Brady). P50127. Side view. Sample NB 9450. $\times 100$.
- Figs 18a, b *Gavelinopsis* sp. P50128. Ventral and dorsal views. Sample NB 9447. $\times 100$.
- Figs 19a, b, 20 *Cymbaloporeta plana* (Cushman). Figs 19a, b, P50130, P50129. Dorsal and ventral side of 'Tretomphalus'-form. Fig. 20, P50131. Ventral side of specimen without float-chamber. All specimens from sample NB 9449. $\times 75$.



DISTRIBUTION. *Fossil*: Upper Miocene/Lower Pliocene of Fiji (Kleinpell 1954); Pliocene of Japan (Asano 1951*d*). *Recent*: Recorded from Japan to New South Wales and New Zealand, and from the Kerimba Islands (Mozambique).

Subfamily BAGGININAE Cushman, 1927

Genus *CANCERIS* de Montfort, 1808

Type-species: *Nautilus auricula* Fichtel & Moll, 1798.

Canceris auriculus (Fichtel & Moll)

Pl. 5, fig. 10

- 1798 *Nautilus auricula* Fichtel & Moll var. α : 108; pl. 20, figs a-c; var. β : 110; pl. 20, figs d-f.
 1921 *Pulvinulina auricula* (Fichtel & Moll) Cushman: 329; pl. 69, figs 3a-c.
 1931 *Canceris auricula* (Fichtel & Moll) Hada: 139, text-figs 94a-c.
 1939 *Canceris auricula* (Fichtel & Moll); Le Roy: 259; pl. 3, figs 1-3.
 1941 *Canceris auriculus* (Fichtel & Moll); Le Roy: 41; pl. 2, figs 79-81.
 1941*b* *Canceris auriculus* (Fichtel & Moll); Le Roy: 117; pl. 3, figs 7-9, 16-18.
 1942 *Canceris auriculus* (Fichtel & Moll); Cushman & Todd: 74; pl. 18, figs 1-11.
 1944 *Canceris auriculus* (Fichtel & Moll); Le Roy: 36; pl. 3, figs 4-9.
 1949 *Canceris auriculus* (Fichtel & Moll); Said: 38; pl. 4, fig. 9.
 1951*d* *Canceris auriculus* (Fichtel & Moll); Asano: 19, text-figs 144, 145.
 1956 *Canceris auricula* (Fichtel & Moll); Bhatia: 23; pl. 5, figs 5a, b.
 1959 *Canceris auriculus* (Fichtel & Moll); Graham & Militante: 91; pl. 13, figs 18a, b.
 1960 *Canceris auriculus* (Fichtel & Moll); Chang: pl. 14, figs 8a-c.
 1963 *Canceris auriculus* (Fichtel & Moll); Matsunaga: pl. 47, figs 8a, b.
 1964 *Canceris auriculus* (Fichtel & Moll); Le Roy: F39; pl. 6, figs 23, 24.
 ? 1964 *Canceris auriculus* (Fichtel & Moll); Carter: 84; pl. 5, figs 87-89.
 1965 *Canceris auriculus* (Fichtel & Moll); Todd: 22; pl. 5, figs 5a-c.
 1966 *Canceris auriculus* (Fichtel & Moll); Belford: 96; pl. 15, figs 1-5.
 1968 *Canceris auriculus* (Fichtel & Moll); Antony: 97; pl. 7, figs 5a, b.
 1971 *Canceris auricula* (Fichtel & Moll); Rao: 170 (table), text-fig. 52.
 1974 *Canceris auriculus* (Fichtel & Moll); Lutze: 29; pl. 6, figs 108, 109.

MATERIAL 22 specimens. NB 9449, 9450, 9460.

VARIATION. Length 0.35-0.77 mm, breadth 0.23-0.58 mm, thickness 0.15-0.24 mm. Number of chambers 7-8.

REMARKS. For comments on this species see Cushman & Todd (1942), who figured topotypes and whose illustrations (pl. 18, figs 4a-c) have formed the basis for subsequent identifications; Haynes (1973: 147) compares and contrasts it with the closely-related *Canceris oblongus* Williamson.

The specific name has been variously construed as *auriculus*, *auricula* and *auriculatus*, the last-mentioned name being modified without reason by de Montfort (1808: 267) from Fichtel & Moll's original name. The gender of *Canceris* is discussed by MacFadyen & Kenny (1934: 180) who concluded that it should be taken as being masculine.

DISTRIBUTION. *Fossil*: Miocene of Sumatra (Le Roy 1939, 1944) and Taiwan (Chang 1960); late Tertiary (? Upper Miocene-Lower Pliocene) of east Borneo (Le Roy 1941); Pliocene of Japan (Asano 1951*d*, Matsunaga 1963), Okinawa (Le Roy 1964), New Guinea (Belford 1966) and Victoria, Australia (? Carter 1964); Plio-Pleistocene of Java (Le Roy 1941*b*). The types are from the Pliocene of Italy (Fichtel & Moll 1798, Cushman & Todd 1942) (= var. α) and the Recent of the Mediterranean (= var. β). *Recent*: This species appears to be common throughout the Indo-Pacific at the present day.

Canceris sp.

Pl. 5, fig. 5

MATERIAL. 9 specimens. NB 9447, 9449.

VARIATION. Length 0.20–0.35 mm, breadth 0.18–0.26 mm, thickness 0.15–0.21 mm. Number of chambers 7–13, with 5–6 in the final whorl.

REMARKS. A small species with lobulate periphery. It may have affinities with *Baggina gibba* Cushman & Todd (1944a: 104; pl. 16, figs 8a–c) and the *Discorbina rugosa* d'Orbigny of Egger (1893: 191; pl. 15, figs 1–3). The umbilical area is open in larger specimens, closed in smaller, usually with a lip. The former features are common to both *Baggina* and *Valvulineria*, while the apertural lip suggests *Cancris*.

Family GLABRATELLIDAE Loeblich & Tappan, 1964

Genus *SCHACKOINELLA* Weinhandl, 1958

Type-species: *Schackoinella sarmatica* Weinhandl, 1958.

'*Schackoinella*' *globosa* (Millett)²

Pl. 5, figs 11, 12a, b; Pl. 10, fig. 6

1903a *Discorbina imperatoria* (d'Orbigny) var. *globosa* Millett: 701; pl. 7, figs 6a, b.

1915 *Rotalia erinacea* Heron-Allen & Earland: 720; pl. 53, figs 23–26.

1963 '*Eponides*' *globosus* (Millett) Ujiie: 233; pl. 1, figs 27a–c only.

1967 *Pararotalia minuta* (Takayanagi); Matoba: 256; pl. 27, figs 5a, b (*non Rotalia* ? *minuta* Takayanagi, 1955).

1967 *Pararotalia minuta* (Takayanagi) var. Matoba: 256; pl. 27, figs 6a, b.

1968 *Pararotalia* cf. *imperatoria* (d'Orbigny) var. *globosa* (Millett); Chiji & Lopez: 109; pl. 12, figs 5a–c.

1971 *Schackoinella sarmatica* Weinhandl; Haman & Christensen: 44, text-figs 1–3 (*non S. sarmatica* Weinhandl 1958).

MATERIAL. 43 specimens. NB 9447, 9449, 9450.

VARIATION. Maximum diameter 0.14–0.25 mm, thickness 0.07–0.15 mm. Number of chambers in last whorl 5–6.

REMARKS. This small, calcareous, monolamellar, perforate, almost planoconvex species bears one spine on each of the later-formed chambers; the coil is a low trochospire. The umbilical area is infilled thus obscuring the aperture, but it is probably umbilical extra-umbilical.

Heron-Allen & Earland (1915) found that their material from Kerimba was conspecific with Millett's (1903a) types. Unfortunately, Millett's types have not been isolated in the collections of the British Museum (Natural History) and therefore it has only been possible to compare the Togopi specimens with *R. erinacea* Heron-Allen & Earland. We consider them to be conspecific. These authors' new name, however, is not now necessary: at the time (1915) they referred the species to *Rotalia* and thus rightly considered the name *globosa* was preoccupied by *Nonionina globosa* von Hagenow, a Cretaceous species from Germany, which was also, they believed, a *Rotalia*. As the name *globosa* is a secondary homonym it can be used for our form, as the two species are certainly not congeneric (see I.C.Z.N. code, articles 57 and 59c). Millett's name, furthermore, is acceptable as a taxon in the species-group as it is published with the term 'variety' before 1961 and therefore is to be interpreted as denoting subspecific rank (articles 45d(i), 45e(i)). Article 46 states that at the same time it is available as a specific name.

Specimens of *Schackoinella sarmatica* identified by Haman & Christensen from the Yellow Sea have been studied by us under the scanning electron microscope. They are probably juveniles of the present species. It is considered better to place this species in *Schackoinella*, as defined by Loeblich & Tappan (1964: C591), than in *Pararotalia*, the apertural characteristics of which are very different. Recently the suprageneric position of *Schackoinella* within the Rotaliina has been disputed by El-Naggar (1971), who would include it within the Globigerinacea.

We believe that *S. globosa* may have been confused with *Rotalia murrayi* Heron-Allen & Earland (1915: 721; pl. 53, figs 27–34) by some earlier workers. At Kerimba, the type area for both species, they occur together in abundance only at stations 7 and 8. In size they are closely similar,

² See Postscript, p. 106; species transferred to *Murrayinella* Farias, 1977 (? Rotaliidae).

but '*Rotalia* *murrayi*' is clearly separated by the coarse rugosity of the test which in places is projected into 'acute papillae' as described by Heron-Allen & Earland.

DISTRIBUTION. *Fossil*: Plio-Pleistocene (Matoba 1967) and Holocene (Ujiié 1963) of Japan. *Recent*: Malay Archipelago (Millett 1903a), Kerimba Archipelago, East Africa (Heron-Allen & Earland 1915), Tanabe Bay, Japan (Chiji & Lopez 1968) and the Yellow Sea (Haman & Christensen 1971).

Family **SIPHONINIDAE** Cushman, 1927

Genus **SIPHONINOIDES** Cushman, 1927

Type-species: *Planorbulina echinata* Brady, 1879.

Siphoninoides echinatus (Brady)

Pl. 4, fig. 17

- 1879 *Planorbulina echinata* Brady : 283; pl. 8, figs 31a-c.
 1884 *Truncatulina echinata* (Brady) Brady : 670; pl. 96, figs 9-14.
 1915 *Truncatulina echinata* (Brady); Heron-Allen & Earland : 711; pl. 53, fig. 1.
 1915 *Siphonina echinata* (Brady) Cushman : 42; pl. 18, figs 1-4 (after Brady); text-figs 46, 47.
 ? 1927 *Siphoninoides echinata* (Brady) Cushman : 13; pl. 4, figs ? 7a, b only.
 1949 *Siphoninoides echinata* (Brady); Said : 38; pl. 4, fig. 6.
 1954 *Siphoninoides echinata* (Brady); Cushman, Todd & Post : 361; pl. 89, figs 31, 32.
 1957 *Siphoninoides echinata* (Brady); Todd : 290 (table); pl. 91, figs 7a, b.
 1959 *Siphoninoides echinatus* (Brady); Graham & Militante : 102; pl. 16, figs 2a, b.
 1960 *Siphoninoides echinata* (Brady); Barker : 198; pl. 96, figs 9-14 (after Brady).
 1965 *Siphoninoides echinatus* (Brady); Todd : 23; pl. 15, figs 5, 6.
 1969 *Siphoninoides echinatus* (Brady); Resig : 84; pl. 5, fig. 5.

MATERIAL. 8 specimens. NB 9447, 9450.

VARIATION. Maximum diameter 0.21-0.32 mm.

REMARKS. Hofker (1970 : 32; pl. 33) discusses *Siphoninoides* from the Caribbean and tentatively assigns it to the Glabratellidae. Unfortunately we are not in a position to verify his findings due to lack of material.

Western Pacific material from the 'Challenger' and Millett collections shows that the strength and number of the spines and prominence of the sutures in the last whorl are variable in this species.

The correct ending for the specific name is *echinatus*. According to MacFadyen & Kenny (1934) all genera ending in *-oides* should be taken as being masculine.

DISTRIBUTION. *Fossil*: Pleistocene, Ewa Borehole, Hawaii (Resig 1969). There is a further possible fossil record from the Miocene of Victoria, Australia. *Recent*: Common in the western Pacific islands (excluding Japan). Said (1949) records it from the Red Sea.

Family **EPISTOMARIIDAE** Hofker, 1954

Genus **EPISTOMAROIDES** Uchio, 1952

Type-species: *Discorbina polystomelloides* Parker & Jones, 1865.

Epistomaroides polystomelloides (Parker & Jones)

Pl. 5, figs 1, 2; Pl. 10, fig. 17

- 1865 *Discorbina polystomelloides* Parker & Jones : 421; pl. 19, figs 8a-c.
 1884 *Discorbina polystomelloides* Parker & Jones; Brady : 652; pl. 91, figs 1a-c.
 1915 *Discorbina polystomelloides* Parker & Jones; Heron-Allen & Earland : 698; pl. 52, figs 19-23.
 1927 *Rotalia polystomelloides* (Parker & Jones) Hofker : 35; pl. 16, figs 1-6.
 1938 (?) *Epistomaria polystomelloides* (Parker & Jones); Howchin & Parr : 303; pl. 17, figs (? 5, ? 6), 7, 11-13.
 1952 *Epistomaroides polystomelloides* (Parker & Jones) Uchio : 158; pl. 7, figs 1a-3c.

- 1954 *Epistomaroides polystomelloides* (Parker & Jones); Cushman, Todd & Post : 360; pl. 89, fig. 26.
 ? 1954 *Epistomaria polystomelloides* (Parker & Jones); Crespin : 45; pl. 6, figs 8a, b.
 1957 *Epistomaroides polystomelloides* (Parker & Jones); Todd : 290 (table); pl. 93, figs 10a-c.
 1959 *Epistomaroides rimosus* (Parker & Jones); Graham & Militante : 94; pl. 14, figs 4a-c (*non Discorbina rimosa* Parker & Jones, 1862).
 1960 *Epistomaroides polystomelloides* (Parker & Jones); Barker : 188; pl. 91, figs 1a-c (after Brady).
 1965 *Epistomaroides polystomelloides* (Parker & Jones); Le Calvez : 191; pl. 13, fig. 2.
 1965 *Epistomaroides polystomelloides* (Parker & Jones); Todd : 25; pl. 10, figs 5, 6a-c.
 1969 *Epistomaroides polystomelloides* (Parker & Jones); Resig : 59; pl. 5, figs 10a, b.

MATERIAL. 23 specimens. NB 9447, 9449, 9450.

VARIATION. Maximum diameter 0.41–1.25 mm, thickness 0.12–0.35 mm. Number of chambers in first whorl 5–6, second whorl 5–9, final whorl 7–10.

REMARKS. Loeblich & Tappan (1964) rediagnosed the genera *Epistomaroides* and *Epistomaria* and selected lectotypes for their respective type-species *Discorbina polystomelloides* Parker & Jones and *Discorbina rimosa* Parker & Jones. *D. rimosa*, according to them, is restricted to the Eocene of Europe. All the Recent Indo-Pacific specimens labelled *D. rimosa* in the Parker Collection (British Museum (Natural History)) are without exception clearly referable to *D. polystomelloides*, as are Parker & Jones' Recent records of *D. rimosa* from the Australian coral reefs (*in* Carpenter 1862) and India (1865); similarly, Graham & Militante's specimen (1959 : pl. 14, figs 4a-c) from the Philippines is almost certainly *D. polystomelloides*.

The paralectotypes of *Epistomaroides polystomelloides* (BM(NH) no. ZF 3602) show that there is a considerable range of variation within the species from a coarsely roughened test (see Parker & Jones' type-figure) to one where surface ornament is reduced and the septal bridges are clearly defined (see specimens illustrated by Heron-Allen & Earland 1915).

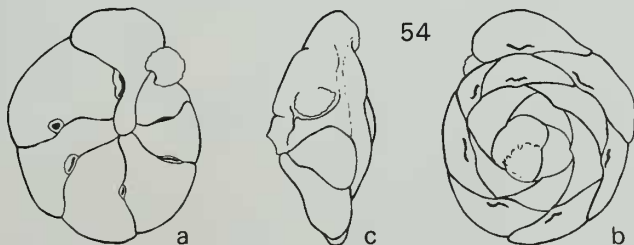
DISTRIBUTION. *Fossil*: Pliocene of South Australia (Howchin & Parr 1938, Crespin 1954); Pleistocene of Hawaii (Resig 1969). *Recent*: Widespread in the western Pacific from Japan to Australia, with two records from east Africa (Comores, Le Calvez 1965, and Kerimba Archipelagos, Heron-Allen & Earland 1915).

Genus *PSEUDOEAPONIDES* Uchio *in* Kawai *et al.*, 1950

Type-species: *Pseudoeponides japonica* Uchio, 1950.

Pseudoeponides japonicus Uchio Figs 54a-c

- 1950 *Pseudoeponides japonica* Uchio *in* Kawai *et al.* : 190, text-fig. 16.
 1950 *Epistomaria* (*Epistomariella*) *miurensis* Kuwano : 315; figs 3a-c, 10.
 1951 *Pseudoeponides japonicus* Uchio; Uchio : 38; pl. 3, figs 1a-c.
 1951d *Pseudoeponides japonicus* Uchio; Asano : 19, text-figs 138–140.
 1963 *Pseudoeponides japonica* Uchio; Matsunaga : pl. 45, fig. 7.
 1964 *Pseudoeponides japonicus* Uchio; Le Roy : F39; pl. 9, figs 20–22.
 1967 *Pseudoeponides japonicus* Uchio; Matoba : 256; pl. 26, figs 20a-c.



Figs 54a-c *Pseudoeponides japonicus* Uchio. P50263. Ventral, dorsal and peripheral views.
Sample NB 9449. $\times 90$.

MATERIAL. 5 specimens. NB 9447, 9449.

VARIATION. Maximum diameter 0.26–0.35 mm, thickness 0.16–0.23 mm.

REMARKS. The Togopi specimens agree closely with the type and most subsequent figures except that the supplementary sutural apertural slits on the ventral side tend to be much less conspicuous and less highly curved.

DISTRIBUTION. ? Upper Miocene/Lower Pliocene of Japan (Matsunaga 1963) and Okinawa (Le Roy 1964); Pliocene (Kuwano 1950, Uchio 1950, 1951, Asano 1951*d*) and Plio-Pleistocene of Japan (Matoba 1967). The species does not appear to have been found living today.

Family **ROTALIIDAE** Ehrenberg, 1839

Subfamily **ROTALIINAE** Ehrenberg, 1839

Genus **AMMONIA** Brünnich, 1772

Type-species: *Nautilus beccarii* Linné, 1758.

Ammonia annectens (Parker & Jones)

Pl. 5, fig. 9

1865 *Rotalia beccarii* (Linné) var. *annectens* Parker & Jones: 422; pl. 19, figs 11a–c.

1904 *Rotalia annectens* Parker & Jones; Millett: 505; pl. 10, figs 6a–c.

1940 *Streblus annectens* (Parker & Jones) Ishizaki: 58; pl. 3, figs 12a, b, 13a, b.

1956 *Streblus annectens* (Parker & Jones); Bhatia: 22; pl. 3, figs 1, 2.

1961 *Rotalia annectens* Parker & Jones; Huang: 87; pl. 4, figs 10, 11.

1964 *Streblus annectens* (Parker & Jones); Bhatia & Bhalla: 79; pl. 2, figs 1a–c.

1964b *Streblus annectens* (Parker & Jones); Rocha & Ubaldo: 417; pl. 4, figs 3a–c.

1964 *Ammonia annectens* (Parker & Jones) Huang: 50; pl. 2, figs 3a–c; pl. 3, figs 1, 2; text-fig. 3.

MATERIAL. 145 specimens. NB 9448, 9449, 9450, 9452, 9454, 9456/7, 9460.

VARIATION.

	<i>Microspheric form</i>	<i>Megalospheric form</i>
Maximum diameter	1.00–1.61 mm	0.59–1.25 mm
Thickness	0.50–0.85 mm	0.40–0.65 mm
Number of chambers in first whorl	5–6	4–7
Number of chambers in second whorl	7–8	8–12
Number of chambers in third whorl	7–9	9–16
Number of chambers in final whorl	15–22	7–17

Plate 5

Scanning Electron Micrographs

Figs 1, 2 *Epistomaroides polystomelloides* (Parker & Jones). P50132, P50133. Dorsal (spiral) and apertural views. Sample NB 9450. Both specimens $\times 50$.

Fig. 3 *Pararotalia calcar* (d'Orbigny). P50134. Ventral view of ornate specimen akin to *Calcarina nicobarensis* Schwager. Sample NB 9449. $\times 60$.

Fig. 4 *Asterorotalia pulchella* (d'Orbigny). P50135. Ventral view. Sample NB 9452. $\times 60$.

Fig. 5 *Cancris* sp. P50136. Ventral view. Sample NB 9447. $\times 75$.

Figs 6a–c *Ammonia togopiensis* sp. nov. P50137. Apertural, ventral and dorsal views. **Holotype**, sample NB 9449. $\times 30$.

Figs 7a–c *Asterorotalia inspinosa* Huang. P50138. Apertural, ventral and dorsal views. Sample NB 9452. $\times 60$.

Figs 8a, b *Ammonia beccarii* (Linné) var. *tepida* (Cushman). P50139. Dorsal and ventral views. Sample NB 9450. $\times 100$.

Fig. 9 *Ammonia annectens* (Parker & Jones). P50140. Ventral view. Sample NB 9449. $\times 30$.

Fig. 10 *Cancris auriculus* (Fichtel & Moll). P50141. Ventral view. Sample NB 9450. $\times 75$.

Figs 11, 12a, b '*Schackoinella*' *globosa* (Millett). Fig. 11, P50142. Dorsal view. Sample NB 9447.

Figs 12a, b, P50143. Ventral and oblique views. Sample NB 9450. All $\times 200$.



REMARKS. Our specimens compare favourably with the type-figure of Parker & Jones 1865; the external trace of the toothplate clearly distinguishes it from *Streblus yabei* Ishizaki and *Rotalia beccarii* (Linné). The size, prominence and dissection of the umbilical plug, together with the development of the toothplate (protoforamen of Hofker, 1968) are its most striking features.

Examination of the Togopi material and of specimens from Hong Kong in the Parker Collection (BM(NH) no. 1894:4:3:1468) confirms Bhatia's observation (1956: 22) that in *A. annectens* there are two openings on the apertural face: a primary cameral aperture and beneath the umbilical portion of the chamber a toothplate foramen (see Hofker 1968) connected both to that of the previous chamber and to the protoforamen of the previous suture. As, however, the latter is not a true cameral aperture this species conforms to the diagnosis of *Ammonia* given by Loeblich & Tappan (1964: C607) and thus the use of the genus *Rotalidium* stipulated by Hofker (1968: 28) is unnecessary.

DISTRIBUTION. *Fossil*: Pliocene (Huang 1964) and Pleistocene (Huang 1964, Ishizaki 1940) of Taiwan. *Recent*: Hong Kong and Fiji (Parker & Jones 1865), Malay Archipelago (Millett 1904), Singapore (Ishizaki 1940), Penghu Is. (Huang 1961) and various Indian localities (Bhatia 1956, Bhatia & Bhalla 1964, Rocha & Ubaldo 1964b).

Ammonia beccarii (Linné) var. *tepida* (Cushman)

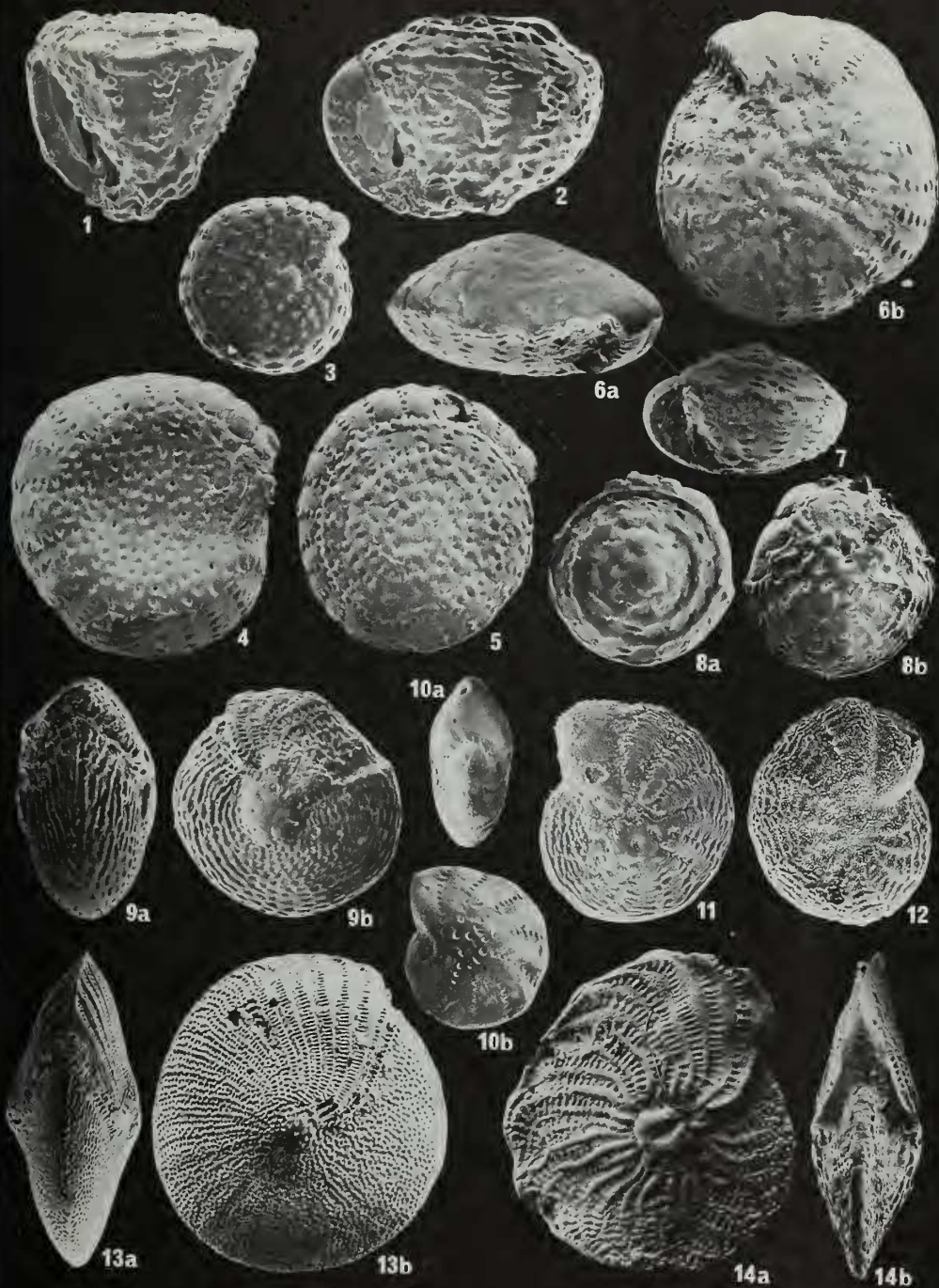
Pl. 5, figs 8a, b

- 1926a *Rotalia beccarii* (Linnaeus) var. *tepida* Cushman : 79; pl. 1.
 1937 *Rotalia hozanensis* Nakamura : 141; pl. 12, figs 4a-c.
 1954 *Rotalia* cf. *R. beccarii* var. *tepida* Cushman; Cushman, Todd & Post : 360; pl. 89, fig. 22.
 1957 *Streblus beccarii* (Linné) var. *tepida* (Cushman) Todd : 290 (table); pl. 9, figs 5a-c.
 1963 *Strebulus beccarii* (Linné) var. *tepida* (Cushman); Chiji : 65; pl. 7, figs 5a-6b, 8a, b (misspelling).
 ? 1963 *Ammonia* cf. *beccarii* (Linné) *tepida* (Cushman) Ujiie : pl. 2, figs 7a-c.
 1964 *Streblus beccarii tepida* (Cushman); Le Roy : F38; pl. 4, figs 16, 17.
 1964 *Ammonia hozanensis* (Nakamura) Huang : 53; pl. 1, figs 4a-c.
 1965 *Streblus beccarii tepida* (Cushman); Todd : 29; pl. 6, figs 1a-c.
 1967 *Ammonia beccarii tepida* (Cushman); Konda : 33 (table); pl. 4, figs 9a, b.
 1968 *Ammonia beccarii* (Linné) var. *tepida* (Cushman); Chiji & Lopez : 104; pl. 12, figs 3a-4b.
 1968 *Ammonia beccarii tepida* (Cushman); Chiji : 58 (table); pl. 3, figs 4a, b.
 1968 *Ammonia hozanensis* (Nakamura); Huang : 90; pl. 5, figs 1-3.
 1971 *Discorbis tepida* (Cushman) Seibold : 44; pl. 5, figs 4-6; pl. 6, figs 1-3; text-fig. 1.

Plate 6

Scanning Electron Micrographs

- Figs 1, 2 *Pseudorotalia schroeteriana* (Parker & Jones). Apertural views. Fig. 1, P50144. Conical megalospheric specimen. Sample NB 9460. Fig. 2, P50145. 'Outgrown' adult megalospheric test. Sample NB 9449. Both specimens $\times 35$.
 Figs 3-5 *Pseudorotalia catilliformis* (Thalman). Fig. 3, P50146. Ventral view of megalospheric form. Sample NB 9454. Fig. 4, P50148. Ventral view of microspheric form. Sample NB 9452. Fig. 5, P50147. Dorsal view of microspheric form. Sample NB 9454. All specimens $\times 20$.
 Figs 6a-8b *Pseudorotalia indopacifica* (Thalman). Figs 6a, b, P50149. Microspheric form, apertural and ventral views. Sample NB 9460. Fig. 7, P50150. Megalospheric form, apertural view. Sample NB 9449. Figs 8a, b, P50151. Megalospheric form, dorsal and ventral views. Sample NB 9460. All specimens $\times 25$.
 Figs 9a, b *Cellanthus hailei* sp. nov. P50152. Apertural and side views. **Holotype**, sample NB 9452. $\times 25$.
 Figs 10a, b *Cribrononion tikotoensis* (Nakamura). P50153. Apertural and side views. Sample NB 9452. $\times 60$.
 Fig. 11 *Parrellina hispidula* (Cushman). P50154. Side view. Sample NB 9449. $\times 60$.
 Fig. 12 *Cribrononion reticulosus* (Cushman). P50155. Side view. Sample NB 9449. $\times 60$.
 Figs 13a, b *Cellanthus adelaidensis* (Howchin & Parr). P50156. Apertural and side views. Sample NB 9449. $\times 25$.
 Figs 14a, b *Elphidium* cf. *fax barbarensense* Nicol. P50157. Side and apertural views. Sample NB 9449. $\times 30$.



MATERIAL. 35 specimens. NB 9446, 9447, 9450.

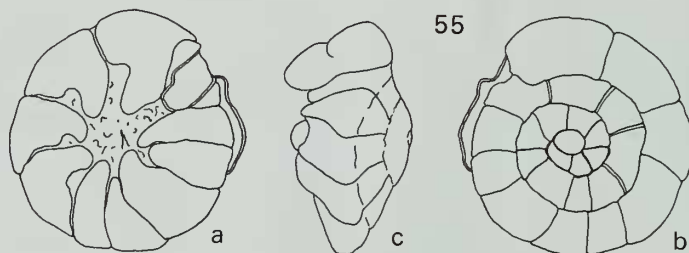
VARIATION. Maximum diameter 0.09–0.35 mm, thickness 0.09–0.20 mm. Number of chambers in last whorl 5–6.

REMARKS. In the Togopi samples this variety of the cosmopolitan species *Ammonia beccarii* shows varying degrees of chamber inflation in the final whorl. The earlier sutures, however, are limbate and flush. The umbilical depression is usually somewhat infilled with secondary material but is not plugged.

We have examined topotypic material housed in the BM(NH) from San Juan Harbour, Puerto Rico and consider ours to fall well within the range of variation found there. *Rotalia hozanensis* Nakamura is clearly a junior synonym as suggested by Huang (1968: 90).

Schnitker (1974) studied cloned cultures of several North American 'species' of *Ammonia*, including *A. tepida* (Cushman), and concluded that only *A. beccarii* (Linné) was a valid taxon. For the present we follow his suggestion that the various 'ecophenotypes' should be recognized on an informal basis as varieties, while at the same time noting the conflicting findings of Seibold (1971), who on studying the internal structure of three members of the *A. beccarii* 'group' from south-west India concluded that only *R. beccarii* var. *sabrina* Shupack was a true *Ammonia*. *R. beccarii* var. *tepida* she placed in *Discorbis*, while *R. pauciloculata* Phleger & Parker was regarded as a species of *Pseudoeponides*. Clearly some further clarification of this problem is necessary.

DISTRIBUTION. *Fossil*: Pliocene of Taiwan (Nakamura 1937, Huang 1968) and Okinawa (Le Roy 1964), Pleistocene of Japan (Chiji 1963, Konda 1967) and Taiwan (Huang 1964) and Holocene of Japan (Ujiié 1963). *Recent*: Widespread in the tropical waters of the Indo-Pacific.



Figs 55a–c *Ammonia takanabensis* (Ishizaki). P50264. Ventral, dorsal and peripheral views. Sample NB 9447. $\times 115$.

Ammonia takanabensis (Ishizaki)

Figs 55a–c

- 1948 *Streblus takanabensis* Ishizaki : 57; pl. 1, figs 5a–c.
- 1948 *Streblus nakamurai* Ishizaki : 62; pl. 1, figs 4a–c.
- 1950 *Rotalia maruhassii* Kuwano : 314, text-figs 2a–c.
- 1951d *Rotalia takanabensis* (Ishizaki) Asano : 16, text-figs 124–126.
- ? 1960 *Streblus* sp. cf. *S. takanabensis* Ishizaki; Chang : pl. 14, figs ? 10a–c only.
- 1964 *Rotalia takanabensis* (Ishizaki); Kikuchi : pl. 5, figs 5, 6.
- 1964 *Streblus takanabensis* Ishizaki; Ishiwada : 14, 15 (table); pl. 6, figs 93a, b.
- 1964 *Ammonia takanabensis* (Ishizaki) Huang : 56; pl. 1, figs 2a–c.
- 1967 *Ammonia takanabensis* (Ishizaki); Matoba : 251; pl. 27, figs 3a–c.
- 1970 *Ammonia takanabensis* (Ishizaki); Kim : 108 (table); pl. 2, figs 4a–c.

MATERIAL. 9 specimens. NB 9447.

VARIATION. Maximum diameter 0.20–0.30 mm, thickness 0.12–0.16 mm. Number of chambers in last whorl 7–9.

DISTRIBUTION. *Fossil:* Pliocene (Huang 1964) and possibly Miocene (Chang 1960) of Taiwan; Pliocene (Ishizaki 1948, Kuwano 1950, Asano 1951*d*) and Pleistocene (Matoba 1967, Kikuchi 1964) of Japan. *Recent:* Japan (Ishiwada 1964), Yellow Sea, west Korea (Kim 1970).

Ammonia togopiensis sp. nov.

Pl. 5, figs 6a–c; Pl. 10, figs 4, 5

1975 *Ammonia ikebei* (Inoue & Nakaseko); Billman & Kartaadipura : 306; pl. 1, figs 2a, b (*non Rotalia ikebei* Inoue & Nakaseko 1951).

DIAGNOSIS. A large inflated trochoid species of *Ammonia* with rounded peripheries. Sutures of strongly convex dorsal side straight and incised. Ventral surface slightly to strongly convex, umbilical area infilled by large raised fissured plug. Chambers usually smooth and coarsely perforate.

NAME. Described from the Togopi Formation.

HOLOTYPE. BM(NH) reg. no. P50137, from NB 9449.

MATERIAL. 40 specimens. NB 9446, 9447, 9449, 9450, 9452, 9456/7, 9460.

DESCRIPTION (Holotype: microspheric). Test calcareous, coarsely perforate, trochoid; periphery lobulate in side view, rounded in edge view. Slightly convex ventral surface showing 15 chambers in the last whorl and deeply fissured sutures lined by very faint bands or beads of hyaline shell material. Chambers slightly inflated, their umbilical ends bearing a non-perforate hyaline flap covering a space which is not in connection with the chamber by an aperture. Umbilical area infilled by a raised imperforate fissured plug. Dorsal surface strongly convex, early chambers obscured by thickening of the basal wall; later, sutures become depressed, radiate and straight giving a characteristic almost square shape to the chambers. In the final whorl chambers become quite inflated. Apertural face flat, confined to the ventral side. Aperture, an areal opening with lip and constriction.

DIMENSIONS (Holotype). Maximum diameter 1.48 mm, thickness 0.75 mm, diameter of plug 0.50 × 0.40 mm, height of apertural face 0.35 mm.

VARIATION. Size range of paratypes:

	<i>Microspheric</i>	<i>Megalospheric</i>
Maximum diameter	0.90–1.75 mm	0.30–0.90 mm
Thickness	0.68–1.00 mm	0.30–0.53 mm
Plug diameter	up to 0.80 mm	up to 0.63 mm

The number of whorls varies from 4 to 8 in the microspheric, and between 2 and 3½ in the megalospheric form. Up to 19 chambers have been recorded in the last whorl of the microspheric form, while 10–13 chambers have been counted in the megalospheric form.

The megalospheric form is always biconvex, while the microspheric form varies between nearly planoconvex and biconvex dependent on the development of the plug (compare Pl. 5, fig. 6a and Pl. 10, fig. 4); in addition, some beading may be developed on the spiral sutures of the former generation. Other variables common to both generations are the prominence of the tooth-plate (very slight in the holotype), situated a quarter of the distance along the chamber from the plug, and the dissection of the plug which may be fissured around its edge or strongly dissected into pluglets.

REMARKS. The only previous record of this species is under the name of *Ammonia ikebei* (Inoue & Nakaseko) from the Kutei Basin, offshore eastern Kalimantan (Borneo). There Billman & Kartaadipura (1975) use it as a Plio-Pleistocene zone fossil. However, their *A. ikebei* Zone, the top of which is placed at the highest stratigraphic occurrence of the nominate species, contains only rare planktonic foraminifera; calcareous nannoplankton are entirely absent. This age assignment is thus based solely on stratigraphic position. Material of this species kindly supplied by Billman from Kerindingan Well no. 1 shows that it occurs also in the preceding *Asanoina* Zone, which they date as Pliocene on nannoplankton.

Billman & Kartaadipura (1975: pl. 1, figs 2a, b) figure a typical megalospheric form of our new species. However, their identification as *R. ikebei*, an obscure Miocene form from Japan subsequently stated by Asano (1951d: 15) to be 'an aberrant form' of *Rotalia nipponica* Asano, is unsatisfactory. Inoue & Nakaseko (1951: text-figs 4a-c) show a much smaller form with curved instead of straight sutures on the dorsal side, many fewer chambers and a relatively smaller non-dissected plug on the ventral side.

DISTRIBUTION. Pliocene and Pleistocene of the Kutei Basin, eastern Borneo. The species does not appear to be living today.

Genus *ASTEROROTALIA* Hofker, 1951

Type-species: *Rotalina (Calcarina) pulchella* d'Orbigny in de la Sagra, 1839.

Asterorotalia pulchella (d'Orbigny)

Figs 56a-59c; Pl. 5, fig. 4

- 1839 *Rotalina (Calcarina) pulchella* d'Orbigny : 80; pl. 5, figs 16-18.
 1884 *Rotalia pulchella* (d'Orbigny) Brady : 710; pl. 115, figs 8a, b.
 1899 *Rotalia pulchella* (d'Orbigny); Flint : 332; pl. 76, fig. 3.
 1927 *Rotalia pulchella* (d'Orbigny); Hofker : 37; pl. 16, figs 7-10.
 1933 *Rotalia trispinosa* Thalmann : 249; pl. 12, figs 1a-c (= Indo-Pacific forms).
 1933 *Rotalia cubana* Thalmann : 249; pl. 12, figs 2a-3b (= Cuban forms).
 1937 *Rotalia trispinosa* Thalmann; Yabe & Asano : 103; pl. 18, fig. 11.
 1951d *Rotalia trispinosa* Thalmann; Asano : 17, text-fig. 127.
 1951b *Asterorotalia pulchella* (d'Orbigny) Hofker : 505, figs 343, 344.
 1956 *Rotalia trispinosa* Thalmann; Marks : 43; pl. 25, figs 45a-f.
 1958 *Asterorotalia pulchella* (d'Orbigny); Reiss & Merling : pl. 2, figs 2, 3; pl. 5, figs 12, 13.
 1958 *Rotalia pulchella* (d'Orbigny); Ganapati & Satyavati : 104; pl. 5, figs 120, 121.
 1960 *Asterorotalia trispinosa* (Thalmann); Barker : 238; pl. 115, figs 8a, b (after Brady).
 1964 *Asterorotalia trispinosa* (Thalmann); Bhatia & Bhalla : 80; pl. 1, figs 10a, b.
 1964 *Asterorotalia trispinosa* (Thalmann); Le Roy : F39; pl. 6, figs 18, 19.
 1964 *Asterorotalia trispinosa* (Thalmann); Huang : 60; pl. 2, figs 10a, b; pl. 3, fig. 9.

Plate 7

Scanning Electron Micrographs

Figs 1, 2a, b *Cellanthus craticulatus* (Fichtel & Moll). Fig. 1, P50158. Side view of microspheric form. Figs 2a, b, P50159. Side and apertural views of megalospheric form. Both specimens from sample NB 9452. $\times 15$.

Figs 3a, b *Cellanthus biperforatus* sp. nov. P50160. Apertural and side views. **Holotype**, sample NB 9452. $\times 25$. (See Fig. 61, p. 84.)

Figs 4a, b *Criboelphidium dentense* sp. nov. P50161. Apertural and side views. **Holotype**, sample NB 9452. $\times 60$.

Figs 5-7 *Elphidiella indopacifica* Germeraad. Fig. 5, P50162. Side view of microspheric form. Figs 6, 7, P50163, P50164. Megalospheric specimens, side and apertural views. All from sample NB 9447. $\times 30$.

Figs 8, 9 *Calcarina hispida* Brady. P50165, P50166. Ventral views. Sample NB 9450. $\times 30$.

Fig. 10 *Gypsina globula* (Reuss). P50167. Side view. Sample NB 9452. $\times 20$.

Fig. 11 *Poroepionides cribrorependus* Asano & Uchio. P50168. Ventral view. Sample NB 9450. $\times 60$.

Fig. 12 *Poroepionides lateralis* (Terquem). P50169. Ventral view. Sample NB 9450. $\times 60$.

Fig. 13 *Cymbaloporella squammosa* (d'Orbigny). P50170. Dorsal view. Sample NB 9449. $\times 45$.

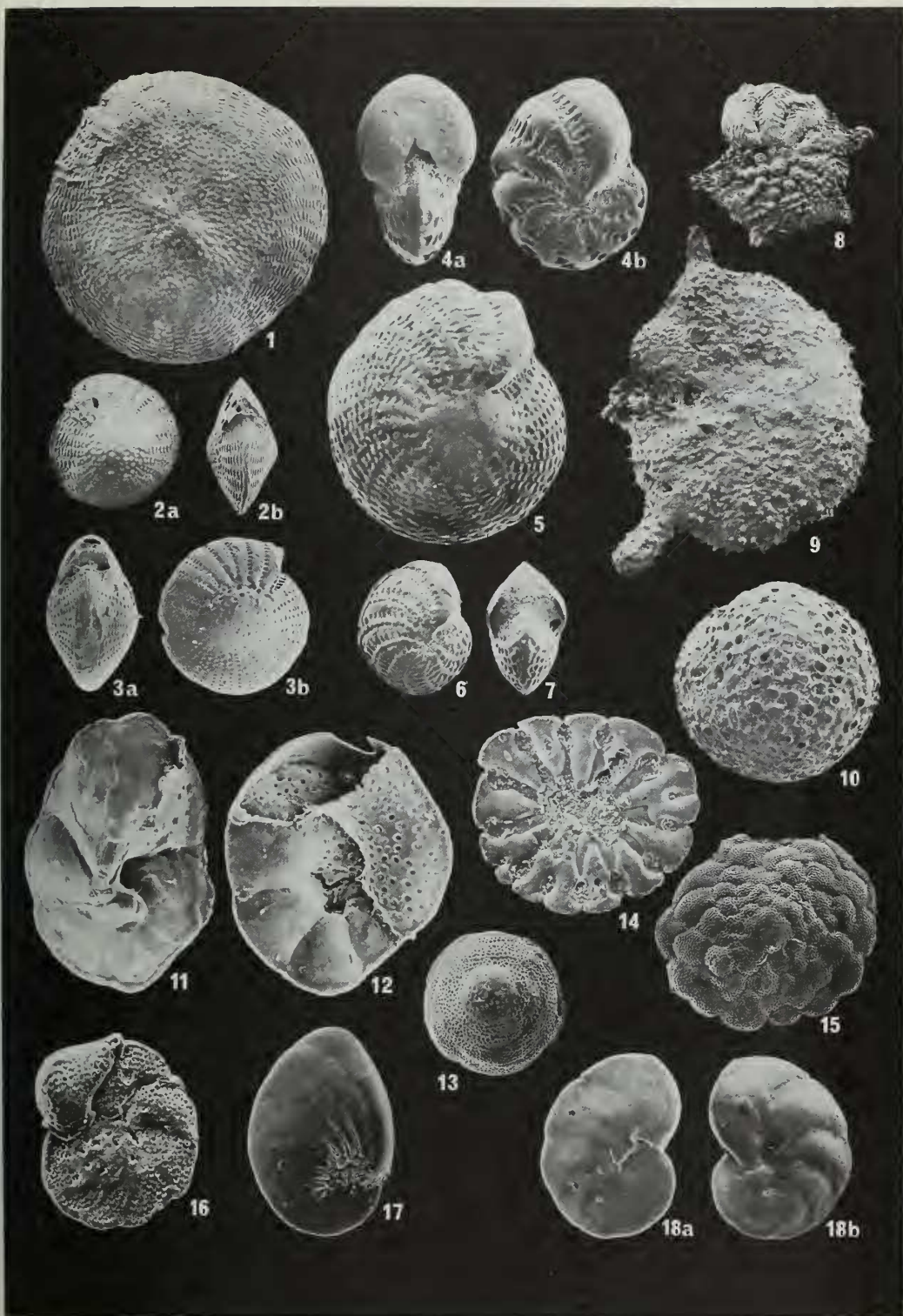
Figs 14, 15 *Cymbaloporella bradyi* (Cushman). Fig. 14, P50171. Ventral view. Sample NB 9449.

Fig. 15, P50172. Dorsal view. Sample NB 9450. Both specimens $\times 45$.

Fig. 16 *Caribbeanella ogiensis* (Matsunaga). P50173. Dorsal view. Sample NB 9450. $\times 60$. (See Fig. 64, p. 101.)

Fig. 17 *Florilus asanoi* nom. nov. P50174. Side view. Sample NB 9452. $\times 80$. (See Fig. 70, p. 104.)

Figs 18a, b *Hanzawaia nipponica* Asano. P50175. Dorsal (spiral) and ventral views. Sample NB 9450. $\times 100$.



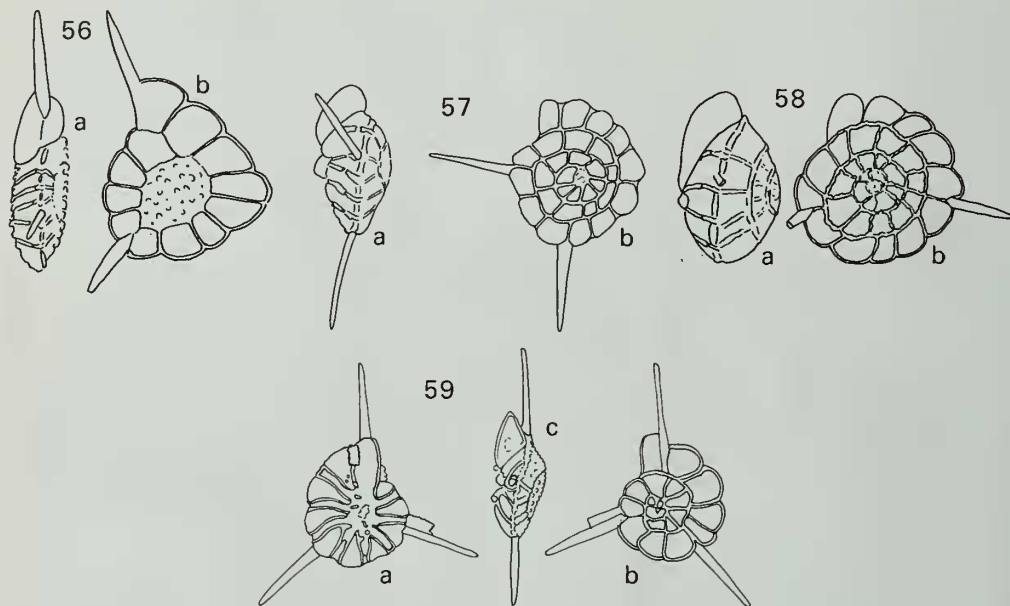
1968 *Asterorotalia trispinosa* (Thalmann); Bhalla : 382; pl. 2, figs 1a, b.

1968 *Asterorotalia pulchella* (d'Orbigny); Hofker : 27; pl. 8, figs 8–10; pl. 9, figs 1–7.

1971 *Asterorotalia pulchella* (d'Orbigny); Huang : 82, text-fig. 4D.

MATERIAL. About 500 specimens. NB 9448, 9449, 9450, 9452, 9453, 9454, 9455, 9456/7, 9460.

VARIATION. Diameter 0.21×0.16 – 0.97×0.68 mm (excluding spines), thickness 0.11 – 0.30 mm.



Figs 56a–59c *Asterorotalia pulchella* (d'Orbigny). 56–58, showing variation in shape as seen in Togopi sample NB 9449. P50265–P50267. Apertural and dorsal views. 56, 57, $\times 35$; 58, $\times 40$. 59a–c, ZF3826. Ventral, dorsal and apertural views. Recent, Dry Harbour, Jamaica. $\times 35$.

Plate 8

Figs 1–10. Light microscopy
Figs 11–17. Scanning Electron Micrographs

Fig. 1 *Amphistegina* cf. *lessonii* d'Orbigny. P50176. Side view. Sample NB 9452. $\times 30$.

Fig. 2 *Amphistegina* cf. *wanneriana* Fischer. P50177. Side view. Sample NB 9450. $\times 30$.

Fig. 3 *Lagena clavata* (d'Orbigny). P50178. Side view. Sample NB 9449. $\times 100$.

Fig. 4 *Lagena gracillima* (Seguenza). P50179. Side view. Sample NB 9449. $\times 50$.

Fig. 5 *Lagena elongata* (Ehrenberg). P50180. Side view. Sample NB 9449. $\times 50$.

Fig. 6 *Marginopora* cf. *vertebralis* de Blainville. P50181. Side view. Sample NB 9449. $\times 30$.

Fig. 7 *Sigmoidella elegantissima* (Parker & Jones). P50182. Side view. Sample NB 9450. $\times 40$.

Fig. 8 *Peneroplis planatus* (Fichtel & Moll) var. *annulata* nov. P50184. Side view. Sample NB 9452. $\times 15$.

Figs 9, 10 *Heterostegina* sp. Fig. 9, P50185. Split specimen showing early part of the test. Sample NB 9452. $\times 15$. Fig. 10, P50186. External view. Sample NB 9452. $\times 10$.

Fig. 11 *Alveolinella quoyi* (d'Orbigny). P50187. Detail of part of apertural face. Sample NB 9452. Scale = $100 \mu\text{m}$.

Fig. 12 *Globigerina quinqueloba* Natland. P50188. Oblique ventral view of broken specimen. Sample NB 9447. $\times 175$.

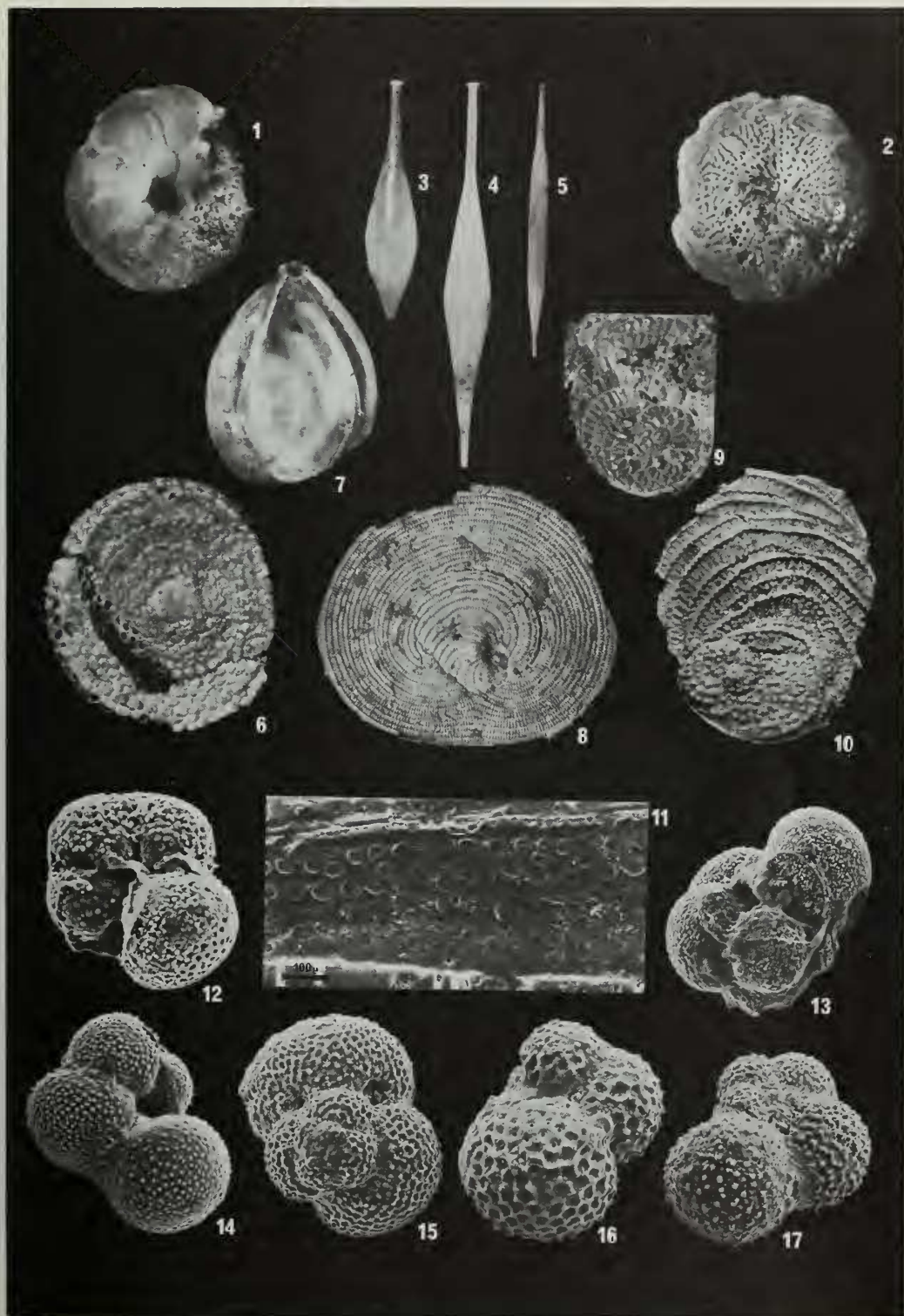
Fig. 13 *Globigerinita glutinata* (Egger). P50189. Oblique peripheral view of broken specimen. Sample NB 9449. $\times 200$.

Fig. 14 *Globigerina bulloides* d'Orbigny. P50190. Oblique ventral view. Sample NB 9450. $\times 175$.

Fig. 15 *Globigerinoides ruber* (d'Orbigny). P50191. Dorsal view. Sample NB 9449. $\times 100$.

Fig. 16 *Globigerinoides sacculifer* (Brady). P50192. Oblique ventral view. Sample NB 9460. $\times 150$.

Fig. 17 *Hastigerina siphonifera* (d'Orbigny). P50193. Oblique side view. Sample NB 9460. $\times 125$.



REMARKS. The species occurs in all but the highest samples in the Togopi Formation and is most common in the middle of the succession. In the two lowermost samples (NB 9456/7, 9455) it is rare, poorly preserved and weakly ornamented, but from NB 9454 upwards *A. pulchella* becomes plentiful and the ornament (bars and beads) on the dorsal surface varies from very sparse to heavy on both chambers and sutures. The test is triangular to subcircular in side view and lenticular to semiglobular in apertural view. The specimens become more inflated higher in the succession and in NB 9449 a grading series is seen between lenticular and semiglobular forms (Figs 56a–58b). In NB 9448, only semiglobular forms occur. This intraspecific variation appears to be greater than is usually observed in Recent sediments from the Malay Archipelago, but there is no evidence in our samples of the evolutionary lineage (*A. inspinosa* → *A. pulchella*) postulated by Huang (1971), although it would be expected in rocks of this age. At Togopi, *Asterorotalia inspinosa* (see below) occurs in the same samples as *A. pulchella*.

There is a problem concerning the relationship between the Indo-Pacific and the Caribbean form, called by Thalmann *Rotalia cubana*. The only published record of this species from the Caribbean area appears to be that of d'Orbigny (1839) from Cuba. However, specimens in the Heron-Allen & Earland collection in the BM(NH), labelled Dry Harbour, north Jamaica (Figs 59a–c) seem, in our opinion, identical to many from the Togopi samples and there is, therefore, no reason to continue the use of different specific names for specimens from the two areas.

DISTRIBUTION. *Fossil*: Miocene of Okinawa (Le Roy 1964) and Japan (Asano 1951*d*); Upper Miocene/Lower Pliocene of Java (Yabe & Asano 1937); Pleistocene of Taiwan (Huang 1964, 1971) and Java (Marks 1956). *Recent*: Appears to be confined in our area to Indonesia and the coasts of India.

Asterorotalia inspinosa Huang

Pl. 5, figs 7a–c; Pl. 10, fig. 3

1963 *Rotalia nipponica* Asano; Matsunaga : pl. 45, figs 9a–c (*non R. nipponica* Asano 1936).

1964 *Ammonia nipponica* (Asano) Huang : 54; pl. 2, figs 1a–c.

1971 *Asterorotalia inspinosa* Huang : 83; pl. 1, figs 1a–5c; text-fig. 4A.

MATERIAL. 295 specimens. NB 9449, 9450, 9452, 9460.

VARIATION.

	<i>Microspheric forms</i> (two specimens)	<i>Megalospheric forms</i>
Maximum diameter	0.64 mm	0.40–0.92 mm
Thickness	0.38 mm	0.20–0.48 mm
Number of whorls	4	3–4
Number of chambers in first whorl	7	5
Number of chambers in second whorl	7	8–9
Number of chambers in third whorl	10	9–11
Number of chambers in fourth whorl	11	11

REMARKS. Although lacking spines this species is retained in *Asterorotalia* since it has sutural plates on the ventral side.

In the Togopi specimens the beading on either side of the ventral sutures varies in prominence and density. The umbilical plug may be pronounced (for example in many specimens of sample NB 9450) or partially or completely covered (see Pl. 5, fig. 7b), its presence being only discovered by dissection or thin-sectioning. The cameral aperture is interiomarginal with lips; the plates of the labial apertures are much shorter than in the type-species.

DISTRIBUTION. Pliocene of Japan (Matsunaga 1963); late Miocene to late Pliocene of Taiwan (Huang 1964, 1971).

Genus *PARAROTALIA* Le Calvez, 1949

Type-species: *Rotalia inermis* Terquem, 1882.

Pararotalia calcar (d'Orbigny)

Pl. 5, fig. 3

- 1826 *Calcarina calcar* d'Orbigny : 276, no. 1; modèle 34.
 1865a *Calcarina calcar* d'Orbigny; Parker, Jones & Brady : 24; pl. 3, fig. 87 (after d'Orbigny's model).
 1866 *Calcarina nicobarensis* Schwager : 261; pl. 7, fig. 3.
 1884 *Rotalia calcar* (d'Orbigny) Brady : 709; pl. 108, figs 3a-c only.
 1893 *Rotalia calcar* (d'Orbigny); Egger : 423; pl. 19, figs 1-3.
 1915 *Rotalia calcar* (d'Orbigny); Cushman : 69; pl. 28, figs 2a-c; pl. 29, figs 2a-c.
 1921 *Rotalia calcar* (d'Orbigny); Cushman : 350; pl. 71, figs 3a, b.
 1927 *Rotalia calcar* (d'Orbigny); Hofker : 37; pl. 17, figs 1-13.
 1934 *Rotalia calcar* (d'Orbigny)?; Caudri : 146; pl. 5, figs 7-9.
 1941a *Rotalia calcar* (d'Orbigny); Le Roy : 84; pl. 7, figs 1-3.
 1946 *Calcarina calcar* d'Orbigny; Germeraad : 70; pl. 4, fig. 1.
 1946 *Calcarina umbilicata* Germeraad : 71; pl. 4, figs 2-5.
 1954 *Rotalia calcar* (d'Orbigny); Kleinpell : 61; pl. 7, figs 5, 6.
 1954 *Rotalia calcar* (d'Orbigny); Todd & Post : 560; pl. 202, figs 1a-c; pl. 203, figs 2, 3a, b.
 1958 *Rotalia calcar* (d'Orbigny); Sethulekshmi Amma : 71; pl. 3, figs 113a, b.
 1959 '*Rotalia*' *calcar* (d'Orbigny); Graham & Militante : 99; pl. 15, figs 2-3c.
 1960 *Calcarina calcar* d'Orbigny; Barker : 222; pl. 108, figs 3a-c only (after Brady).
 1964 *Calcarina calcar* d'Orbigny; Rocha & Ubaldo : 153; pl. 19, figs 5-7.
 1965 *Calcarina calcar* d'Orbigny; Le Calvez : 191; pl. 13, fig. 1.
 1965 *Calcarina calcar* d'Orbigny; Jell, Maxwell & McKellar : 277; pl. 44, figs 5a, b.
 1970 *Pararotalia calcar* (d'Orbigny) Hofker : 55; pl. 41, figs 1-5; pl. 46, fig. 1.

MATERIAL. 26 specimens. NB 9447, 9449, 9450.

VARIATION. Maximum diameter 0.33-0.90 mm, thickness 0.17-0.20 mm.

REMARKS. These specimens are placed in *Pararotalia* as they have laterally elongated chambers, a plugged umbilicus and an interiomarginal and curved intercameral aperture. Ornament is variable and consists of pustules, particularly over the umbilical area, hyaline ridges along the chambers and hispid spines.

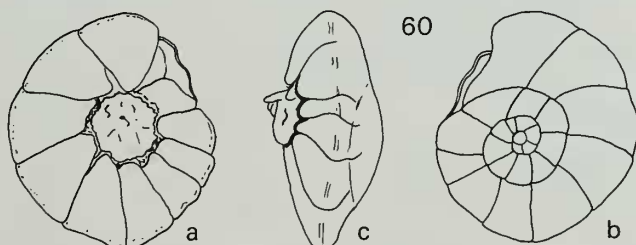
We have examined numerous Recent specimens attributed to *Calcarina calcar* d'Orbigny, including topotypic material from Madagascar, and conclude that the Togopi specimens fall within the range of variation of this species.

DISTRIBUTION. *Fossil*: Miocene of Fiji (Kleinpell 1954) and of Soemba Is., Indonesia (Caudri 1934), Neogene of Kar Nicobar, Indian Ocean (Schwager 1866), 'Young-Neogene' of Ceram Is., Indonesia (Germeraad 1946), post-Miocene of Bikini (Todd & Post 1954), Late Tertiary (? Pliocene) of Siberoet Is., Indonesia (Le Roy 1941a) and a sub-Recent raised beach in northern Timor (Rocha & Ubaldo 1964). *Recent*: Widespread in the Indian Ocean and in the East Indies and west Pacific Islands from Borneo to northern Australia. We know of no records from Japan.

Pararotalia cf. *nipponica* (Asano)

Figs 60a-c

- cf. 1936 *Rotalia nipponica* Asano : 614; pl. 31, figs 2a-c.
 cf. 1937 *Rotalia taiwanica* Nakamura : 141; pl. 12, figs 6a-c.
 cf. 1951d *Rotalia ozawai* Asano : 15, text-figs 115-117.



Figs 60a-c *Pararotalia* cf. *nipponica* (Asano). P50268. Ventral, dorsal and peripheral views. Sample NB 9447. $\times 100$.

MATERIAL. 24 specimens. NB 9446, 9447.

VARIATION. Maximum diameter 0.18–0.29 mm, thickness 0.13–0.21 mm. Number of chambers in last whorl 7–10.

REMARKS. A number of authors (e.g. Ujiie 1966, Bhalla 1972) have considered the possibility that *Rotalia nipponica*, *R. taiwanica* and *R. ozawai* may be conspecific.

R. nipponica is much larger than *R. taiwanica* (the types are twice the size), but Ujiie and Bhalla state the only other differences appear to be that the latter has a more lobulate periphery and smaller number of chambers. *R. ozawai* is similar in size to *R. taiwanica* and differs only in possessing small peripheral spiny projections. Furthermore, these two are often found together in Recent (e.g. Graham & Militante 1959) and fossil (e.g. Huang 1964) sediments. All three have a strong umbilical plug and belong to the genus *Pararotalia*. As all our material is small and of the *P. taiwanica* type we are not able to study variation and therefore can only concur tentatively with the thesis that *P. nipponica* is the only valid taxon.

DISTRIBUTION. *Pararotalia nipponica*, '*P. taiwanica*' and '*P. ozawai*' all have a geological record extending back to the Miocene. They occur widely in the Indo-Pacific today.

Genus *PSEUDOROTALIA* Reiss & Merling, 1958

Type-species: *Rotalia schroeteriana* Parker & Jones in Carpenter, 1862.

Pseudorotalia schroeteriana (Parker & Jones)

Pl. 6, figs 1, 2; Pl. 10, figs 12, 13

1826 *Gyroidina conoides* d'Orbigny : 278, no. 9 (*nom. nud.*).

1853 *Faujasina* sp. Williamson : 87; pl. 10, figs 1–6.

1862 *Rotalia schroeteriana* Parker & Jones in Carpenter : 213; pl. 13, figs 7–9.

1884 *Rotalia schroeteriana* Parker & Jones; Brady : 707; pl. 115, figs 7a–c.

1893 *Rotalia schroeteriana* Parker & Jones; Egger : 422; pl. 19, figs 10–12.

1899 *Rotalia schroeteriana* Parker & Jones; Flint : 332; pl. 76, fig. 1.

1906 *Gyroidina conoides* d'Orbigny; Fornasini : 69; pl. 4, figs 8a, b (d'Orbigny's unpublished figures).

1927 *Rotalia schroeteriana* Parker & Jones; Hofker : 39; pl. 18, figs 1a–4; pl. 19, figs 1–12; pl. 21, figs 1, 2, 7, 11, 13.

1934 *Rotalia conoides* (d'Orbigny) Thalmann : 431; figs 2, 3a–c.

1936 *Rotalia schroeteriana* Parker & Jones; Keijzer : 132; pl. 4, figs 3–5, 7–10; text-fig. 26.

1937 *Rotalia conoides* (d'Orbigny); Yabe & Asano : 104; pl. 18, fig. 9.

1937 *Rotalia schroeteriana* Parker & Jones var. Yabe & Asano : 104; pl. 19, fig. 10.

1940 *Streblus schroeterianus* (Parker & Jones) Ishizaki : 59; pl. 3, figs 5a–6b, 9a–10b; pl. 4, figs 7, 8.

1956 *Rotalia conoidea* (d'Orbigny); Marks : 41; pl. 21, figs 43a–c.

1958 *Pseudorotalia schroeteriana* (Parker & Jones) Reiss & Merling : 13; pl. 1, figs 15–17; pl. 2, fig. 1; pl. 5, fig. 15.

1958 *Rotalia papillosa* Brady; Ganapati & Satyavati : 100 (list); pl. 5, figs 124, 125 (*non* Brady 1884).

1960 *Streblus schroeterianus* (Parker & Jones); Barker : 238; pl. 115, figs 7a–c (after Brady).

1962 *Rotalia conoides* (d'Orbigny); Visser & Hermes : 60, fig. 65a.

1964 *Pseudorotalia schroeteriana schroeteriana* (Parker & Jones); Huang : 60; pl. 1, fig. 12.

1968 *Pseudorotalia schroeteriana* (Parker & Jones); Hofker : 30; pl. 10, figs 4–18.

1968 *Pseudorotalia schroeteriana* (Parker & Jones); Bhalla : 384; pl. 2, fig. 2.

1971 *Pseudorotalia schroeteriana* (Parker & Jones); Hofker : 31; pl. 73, figs 1–6; pl. 74, figs 1–11.

MATERIAL. 256 specimens. NB 9446, 9448, 9449, 9450, 9452, 9454, 9460.

VARIATION.

	<i>Microspheric</i>	<i>Megalospheric</i>
Maximum diameter	0.90–1.14 mm	0.21–1.50 mm
Thickness	0.90–0.94 mm	0.20–1.20 mm
Number of chambers in first whorl	5	4–7
Number of chambers in second whorl	5–6	6–11
Number of chambers in last whorl	9–11	7–14

REMARKS. In the present material the microspheric form has a flat spiral and a high conical umbilical side with single or double rows of beading along the sutures. The umbilical plug is

added to the apex of the newest chamber but because of the high conical test shape the plug development on earlier chambers remains prominent, simulating a lateral displacement, whereas it is in reality terminal in relation to each chamber. The majority of megalospheric specimens are similar to the microspheric (see Pl. 6, fig. 1; Pl. 10, fig. 12), but some show a tendency, previously noted by Keijzer (1936) and Hofker (1927, 1968 and 1971), to 'outgrow' this shape, and by adding additional whorls with convex peripheries a proportionately much lower test is produced with a truncate ventral apex (see Pl. 6, fig. 2; Pl. 10, fig. 13). The evidence of Keijzer and Hofker, together with our observations on material from the Malay Archipelago, leads us to conclude that the conical form (= '*Gyroidina conoides*' d'Orbigny) is typical of immature specimens and that adults tend to lose their conical shape. In addition to the variation described above, two large megalospheric forms in sample NB 9449 resemble *Asanoina globosa* (Yabe & Asano), but are less trochoid dorsally than the type figure.

The type-specimen of *Rotalia schroeteriana* could not be found despite an extensive search of the Parker & Jones and Carpenter Collections, whilst the only remaining specimen of Williamson's *Faujasina* sp. does not fit the ascribed figure (1853: pl. 10, fig. 3) nor is a locality given. The single specimen recorded by Heron-Allen & Earland (1915) from Kerimba, Mozambique, has rather deeply incised sutures and is not considered conspecific with those from the western Pacific. Belford's figured specimens from the Pliocene of Papua (1966: pl. 70, figs 12-16), likewise, appear to belong to another species.

DISTRIBUTION. *Fossil:* Miocene (Yabe & Asano 1937), Pliocene (Thalmann 1934) and Pleistocene (Marks 1956) of Java; Pliocene of Papua (Hofker 1971) and Taiwan (Ishizaki 1940, Huang 1964); Plio-Pleistocene of western New Guinea (Irian) (Visser & Hermes 1962). *Recent:* Widespread in the tropical western Pacific from Taiwan to Australia and particularly common in the islands of the Malay Archipelago. Also reported from the Bay of Bengal.

Pseudorotalia catilliformis (Thalmann)

Pl. 6, figs 3-5; Pl. 10, figs 10, 11

1934 *Rotalia catilliformis* Thalmann: 437; pl. 11, figs 1-3d.

1937 *Rotalia catilliformis* Thalmann; Yabe & Asano: 104; pl. 19, fig. 10.

1937 *Rotalia tikutoensis* Nakamura: 141; pl. 12, figs 7a-c.

1940 *Streblus tikutoensis* (Nakamura) Ishizaki: 60; pl. 3, figs 14a, b; pl. 4, figs 12, 13 only.

1962 *Rotalia catilliformis* Thalmann; Visser & Hermes: 60, fig. 65c.

1964 *Pseudorotalia schroeteriana tikutoensis* (Nakamura) Huang: 61; pl. 2, figs 9a-c; pl. 3, figs 7, 8.

1966 *Pseudorotalia catilliformis* (Thalmann) Belford: 114; pl. 21, figs 4-10.

1968 *Pseudorotalia catalliformis* (Thalmann); Huang: 91; pl. 3, figs 15-17 (misspelling).

1975 *Pseudorotalia catilliformis* (Thalmann); Billman & Kartaadipura: 306; pl. 1, figs 4a-c.

MATERIAL. 398 specimens. NB ? 9449, 9450, 9452, 9453, 9454, 9455, 9456/7, 9460.

VARIATION.

	<i>Microspheric</i>	<i>Megalospheric</i>
Maximum diameter	1.30-2.26 mm	1.22-1.60 mm
Thickness	0.50-0.74 mm	0.55-0.85 mm
Numbers of chambers in final whorl	16-27	13-23
Number of chambers in second whorl	6	10-17
Number of chambers in first whorl	5	5-10
Number of whorls not exceeding	4½	3½

REMARKS. The microspheric test of the Togoli specimens varies considerably in thickness. There are examples, in a large population in NB 9452, of the very thin specimens with slightly concave venters, as figured by Thalmann (1934), with gradation to the thicker form illustrated in Pl. 6, figs 4, 5, identical to *Rotalia tikutoensis* Nakamura. The plug is very large and highly perforate, usually opaque. The spire is generally low, the dorsal side being only slightly convex, some specimens in NB 9460, however, having a higher spire. The amount of beading on the sutures is variable.

The megalospheric test (Pl. 6, fig. 3) is much smaller, with an acute periphery, and is usually more trochoid. The ventral surface nevertheless is very flat.

Little comparative work has previously been undertaken on *R. catilliformis* and *R. tikutoensis*. The latter was first described from the Pliocene Byoritu beds of Taiwan and was separated from *R. catilliformis* by being less compressed, less concave ventrally and possessing fewer than 25 chambers in the final whorl. Huang (1964) was originally of the opinion that *R. tikutoensis* was a subspecies of *R. schroeteriana* Parker & Jones, but in 1968, having re-examined Nakamura's type, considered it to be synonymous with Thalmann's species, a conclusion with which we agree. We do not consider *Streblus tikutoensis* (Nakamura) of Chang (1960: pl. 2, figs 13a-c), from the upper Miocene of Taiwan, to be conspecific with our material, but it may have affinities with *Rotalia indopacifica* Thalmann.

DISTRIBUTION. *Fossil*: Miocene of Java (Yabe & Asano 1937); Pliocene of Java (Thalmann 1934), Taiwan (Nakamura 1937, Huang 1964 and Ishizaki 1940) and Papua (Belford 1966); Plio-Pleistocene of western New Guinea (Irian) (Visser & Hermes 1962). Billman & Kartaadipura (1975) do not record *P. catilliformis* above the late Miocene in the Kutei Basin of east Borneo. Nevertheless, specimens of their *P. tikutoensis*, which they kindly sent to us from higher in Kerindingan Well no. 1, fall within the variation seen in our material, and thus extend the range of the species up into the Plio-Pleistocene of this area as well. *Recent*: *P. catilliformis* does not appear to be living in the Indo-Pacific today.

Pseudorotalia indopacifica (Thalmann)

Pl. 6, figs 6a-8b; Pl. 10, figs 7-9

- 1899 *Rotalia papillosa* Brady; Flint : 332; pl. 76, fig. 2 (*non* Brady 1884).
 1921 *Rotalia schroeteriana* Parker & Jones; Cushman : 347; pl. 73, figs 1a-c (*non* Parker & Jones in Carpenter 1862).
 1935 *Rotalia indopacifica* Thalmann : 605.
 1940 *Streblus indopacificus* (Thalmann) Ishizaki : 54; pl. 3, figs 1a, b; pl. 4, figs 1-6.
 1951d *Rotalia indopacifica* Thalmann; Asano : 13, text-figs 99, 100.
 1957 *Rotalia indopacifica* Thalmann; Samaniego & Gonzales : 203; pl. 23, figs 10a-c.
 1963 *Pseudorotalia indopacifica* (Thalmann) Huang : pl. 4, figs 23a, b.
 1964 *Pseudorotalia indopacifica* (Thalmann); Huang : 60; pl. 1, figs 7a-c; pl. 3, fig. 4.
 1970 *Pseudorotalia indopacifica* (Thalmann); Kim : 108 (table); pl. 2, figs 6a-c.

MATERIAL. 168 specimens. NB 9448, 9449, 9452, 9453, 9460.

VARIATION.	<i>Microspheric</i>	<i>Megalospheric</i>
Maximum diameter	0.96-2.10 mm	0.41-1.30 mm
Thickness	0.55-1.30 mm	0.28-0.80 mm
Number of chambers in final whorl	16-24	8-18 (usually 13-18)
Number of chambers in second whorl	6-8	7-14
Number of chambers in first whorl	4-6	5-7

REMARKS. Our material has been compared with specimens in the BM(NH) from Albatross Station D5313, China Sea (see Cushman's localities, 1921 : 347). In this sample the microspheric form attains 2.5 mm in diameter and appears to be identical with the type-figure. The megalospheric form is usually 1-2 mm in diameter and has 5-6, 10-11 and 14-16 chambers in the first, second and final whorls. It is either compressed, thus almost equally biconvex, or more highly trochoid dorsally. It has a small plug dissected into beadlets. In both generations the umbilical ends of the chambers have small hyaline flaps and the test is beaded along both spiral and cameral sutures. The canal system opens along the ventral sutures with a double row of pores, a feature characteristic of the genus. In sample NB 9460 some specimens are highly trochoid dorsally, reminiscent of *Rotalia alveiformis* Thalmann (see Pl. 10, fig. 8), but the vast majority are closely similar to the topotypic specimens described above.

DISTRIBUTION. *Fossil*: Miocene of Taiwan (Huang 1963); Pliocene of Taiwan (Huang 1964), Japan (Asano 1951d) and the Philippines (Samaniego & Gonzales 1957). *Recent*: Philippines (Cushman 1921), Korean Yellow Sea (Kim 1970) and Taiwan (Ishizaki 1940); Flint's 'Albatross'

locality is not recorded. Probably it is widespread in the Indo-Pacific at the present day, but has been confused with other species of *Pseudorotalia*.

Family **CALCARINIDAE** Schwager, 1876

Genus **CALCARINA** d'Orbigny, 1826

Type-species: *Nautilus spengleri* Gmelin, 1788.

Calcarina hispida Brady

Pl. 7, figs 1, 2; Pl. 10, fig. 14

1862 *Calcarina* sp. (hispid variety); Carpenter, Parker & Jones : 218; pl. 14, figs 6, 7.

1876 *Calcarina hispida* Brady : 589.

1884 *Calcarina hispida* Brady; Brady : 713; pl. 108, figs 8, 9.

1921 *Calcarina hispida* Brady; Cushman : 356; pl. 75, fig. 4.

1943 *Calcarina hispida* Brady; Gnanamuthu ; 18; pl. 4, figs 9a-c.

1954 *Calcarina hispida* Brady; Cushman, Todd & Post : 363; pl. 90, figs 9-12.

1959 *Calcarina hispida* Brady; Graham & Militante : 106; pl. 17, figs 5a-7b.

1959 *Calcarina spengleri* (Gmelin) Graham & Militante (*pars*) : 107; pl. 17, figs 8a, b, and 13a, b only.

1960 *Tinoporus hispidus* (Brady) Barker : 222; pl. 108, figs 8, 9.

1961 *Calcarina hispida* Brady; Huang : 88; pl. 5, figs 1-4, 20, 21.

1964 *Calcarina spengleri* (Gmelin); Le Roy : F40; pl. 5, fig. 3 (*non Nautilus spengleri* Gmelin 1788).

1965 *Calcarina hispida* Brady; Jell, Maxwell & McKellar : 277; pl. 44, figs 4a, b.

1968 *Calcarina hispida* Brady; Chiji & Lopez : 105; pl. 12, figs 8a, b.

1968 *Calcarina hispida* Brady; Antony : 100; pl. 7, fig. 8.

1970 *Calcarina hispida* Brady; Hofker : 63; pl. 43, figs 5-13; pl. 47, fig. 3.

MATERIAL. 118 specimens. NB 9449, 9450, 9460.

VARIATION. Greatest diameter up to 1.5 mm (excluding spines), thickness up to 0.7 mm. Number of whorls $1\frac{3}{4}$ - $3\frac{1}{2}$, number of chambers in second whorl 9-14.

REMARKS. This highly variable suite of rather poorly preserved specimens closely resembles the *C. hispida/rustica* group. The chambers in the last whorl are prominent or obscure, while in cross section the test varies in its biconvexity, the chamber peripheries being either rounded or acute. The spines, never more than nine, arise at any angle along a suture and are always hispid, a character separating this species from *Calcarina spengleri* (Gmelin) and *C. quoyi* d'Orbigny. The strongly biconvex forms are usually heavily pustulate and very hispid, but flatter specimens with prominent chambers in the last whorl have reduced ornament, what pustules there are being confined to the umbilical region.

In comparison, *Calcarina mayori* Cushman has a less robust test with well-developed spines, while *C. rustica* Todd & Post has grooved spines. Nevertheless, it seems to us that much specific differentiation within this genus is more than usually arbitrary. Insufficient studies have yet been made on the internal structure and variation in external morphology of the test. In particular, we know little about how much spine development is affected by the environment.

DISTRIBUTION. *Fossil*: Pliocene of Okinawa (*C. spengleri* of Le Roy 1964). *Recent*: Widespread in the western Pacific from Japan to Queensland, Australia. Found also around India.

Family **ELPHIDIIDAE** Galloway, 1933

Subfamily **ELPHIDIINAE** Galloway, 1933

Genus **ELPHIDIUM** de Montfort, 1808

Type-species: *Nautilus macellus* Fichtel & Moll var. β Fichtel & Moll, 1798.

Elphidium cf. *fax barbarens* Nicol

Pl. 6, figs 14a, b

cf. 1944 *Elphidium fax barbarens* Nicol : 178; pl. 29, figs 10, 12.

MATERIAL. 11 specimens. NB 9449, 9452.

VARIATION. Maximum diameter 0.63–1.60 mm, thickness 0.33–0.38 mm. Plug diameter 0.18–0.35 mm. Number of chambers in last whorl 25–31.

REMARKS. Our specimens are characterized by a large number of retral bars per chamber and sutures which become strongly limbate towards the umbilicus; the plug usually has a central depression but is non-canalicular. In apertural view the test is keeled with angular peripheries, while the aperture is a series of interiomarginal pores at the base of the face, with areal pores on older chamber faces.

The Togopi specimens seem closest to *Elphidium fax barbarens* of Nicol (1944), a subspecies first described from the Pleistocene of California, but differ in having a poreless plug and sutures which are limbate only at their umbilical ends. Furthermore, a number of different Indo-Pacific forms appear to have been included in Nicol's subspecies and there has been some confusion with *E. crispum* (Linné).

DISTRIBUTION. *E. fax barbarens* auctt. has been reported from Pliocene (Asano 1950) to Recent sediments in the Indo-west Pacific region.

Genus *CELLANTHUS* de Montfort, 1808

Type-species: *Nautilus craticulatus* Fichtel & Moll, 1798.

Cellanthus craticulatus (Fichtel & Moll)

Pl. 7, figs 1, 2a, b; Pl. 10, figs 15, 16

- 1798 *Nautilus craticulatus* Fichtel & Moll : 51; pl. 5, figs h, i, k.
 1862 *Polystomella craticulata* (Fichtel & Moll) Carpenter : 279; pl. 16, figs 1–3, 7–9.
 1884 *Polystomella craticulata* (Fichtel & Moll); Brady : 739; pl. 110, figs 16, 17a, b.
 1893 *Polystomella craticulata* (Fichtel & Moll); Egger : 241; pl. 20, figs 24, 25.
 1911 *Polystomella craticulata* (Fichtel & Moll); Schubert : 91, text-fig. 11.
 1914 *Polystomella craticulata* (Fichtel & Moll); Cushman : 34; pl. 19, figs 4a, b.
 1927 *Polystomella craticulata* (Fichtel & Moll); Hofker : 56; pl. 26, figs 10–15; pl. 27, figs 1–4; pl. 28, figs 4, 8, 10, 11.
 1941a *Elphidium craticulatum* (Fichtel & Moll) Le Roy : 78; pl. 6, figs 34, 35.
 1944 *Elphidium* aff. *craticulatum* (Fichtel & Moll); Le Roy : 24; pl. 8, figs 36, 37.
 1950 *Elphidium craticulatum* (Fichtel & Moll); Asano : 7, text-figs 36, 37.
 1954 *Elphidium craticulatum* (Fichtel & Moll); Kleinpell : 42; pl. 2, fig. 4.
 1958 *Elphidium craticulatum* (Fichtel & Moll); Ganapati & Satyavati : 125 (list); pl. 3, figs 87, 88.
 1959 *Elphidium craticulatum* (Fichtel & Moll); Graham & Militante : 74; pl. 11, figs 9–12b.
 1960 *Elphidium craticulatum* (Fichtel & Moll); Barker : 228; pl. 110, figs 16, 17a, b (after Brady).
 1961 *Elphidium craticulatum* (Fichtel & Moll); Braga : 127; pl. 13, figs 4, 5.
 1963 *Elphidium craticulatum* (Fichtel & Moll); Huang : pl. 2, fig. 47.
 1964 *Elphidium craticulatum* (Fichtel & Moll); Rocha & Ubaldo : 147; pl. 18, fig. 5.
 1964a *Elphidium craticulatum* (Fichtel & Moll); Rocha & Ubaldo : 416; pl. 3, fig. 7.
 1965 *Elphidium craticulatum* (Fichtel & Moll); Rocha : 420; pl. 5, fig. 3.
 1965 *Elphidium craticulatum* (Fichtel & Moll); Jell, Maxwell & McKellar : 278; pl. 44, figs 7a, b.
 1968 *Elphidium craticulatum* (Fichtel & Moll); Antony : 61; pl. 4, fig. 3.
 1968 *Elphidium craticulatum* (Fichtel & Moll); Albani : 111; pl. 9, figs 19, 20.
 1968 *Cellanthus craticulatus* (Fichtel & Moll) Chiji & Lopez : 105; pl. 13, fig. 9.
 1971 *Cellanthus craticulatus* (Fichtel & Moll); Hofker : 171; pl. 101, figs 11–14; pl. 107, figs 1, 2, 7.

MATERIAL. 55 specimens. NB 9447, 9449, 9450, 9452, 9454, 9460.

VARIATION.

	<i>Microspheric</i>	<i>Megalospheric</i>
Maximum diameter	1.15–4.50 mm	0.32–1.45 mm
Thickness	0.50–1.60 mm	0.32–0.85 mm
Plug diameter	0.50–3.20 mm	0.23–0.70 mm
Number of chambers in final whorl	31–60	25–28

REMARKS. A *Cellanthus* with large caniculate plug, spiral canal, double septa and diverging canals opening into a double row of pores along the sutures; see Hofker (1927, 1971) for internal morphological details.

Sexual dimorphism in the adult is pronounced, the large lenticular microspheric specimens, one of few fossil records of this dimorph, having a huge plug obscuring most of the test. In juvenile forms, however, sexual dimorphism can only be recognized in thin sections.

Elphidium javanum Yabe & Asano (1937: 102; pl. 18, figs 10a, b), from the Miocene of western Java, and *E. taiwanum* Nakamura (1937: 193; pl. 11, figs 9a, b), from the Neogene of Taiwan, may prove to be conspecific with *Cellanthus craticulatus* (Fichtel & Moll). Furthermore, *E. batavum* Hofker (1968: 32; pl. 11, figs 8–19), from the Recent sediments of the Bay of Jakarta, Java, has doubtful validity. In 1968 Hofker stated that his new species was a true *Elphidium*, not a *Cellanthus*, forming a link between *E. crispum* and *C. craticulatus*, and cited Cushman's *E. craticulatum* from Tonga (1933: 48; pl. 11, fig. 5), as being conspecific. In 1971, however, he included this reference, without comment, in his synonymy of *C. craticulatus*.

DISTRIBUTION. *Fossil*: Miocene of the Bismarck Archipelago (Schubert 1911), western Java (Le Roy 1944) and Fiji (Kleinpell 1954); Late Tertiary (? Pliocene) of Siberot Island, Indonesia (Le Roy 1941a); Pliocene of Japan (Asano 1950) and Taiwan (Huang 1963) and a sub-Recent raised beach in Timor (Rocha & Ubaldo 1964). *Recent*: A widely distributed shallow-water species in the western Pacific, from Japan to Australia, and Indian Oceans – the east coast of Africa, Arabian Gulf (type locality) and Indian coasts.

Cellanthus adelaidensis (Howchin & Parr)

Pl. 6, figs 13a, b; Pl. 10, figs 18, 19

1938 *Elphidium adelaidense* Howchin & Parr: 300; pl. 18, fig. 7; pl. 19, figs 5, 6.

1938 *Elphidium* sp. cf. *adelaidense* Howchin & Parr: 308; pl. 17, fig. 3.

1975 *Elphidium* sp. 14 Billman & Kartaadipura: 306; pl. 1, fig. 6.

MATERIAL. 41 specimens. NB 9449, 9450, 9452, 9460.

VARIATION.

	<i>Microspheric</i> (1 specimen)	<i>Megalospheric</i>
Maximum diameter	2.55 mm	0.70–2.20 mm
Thickness	1.05 mm	0.18–0.90 mm
Number of whorls	7 $\frac{3}{4}$	1–5
Number of chambers in first whorl	5	8–10
Number of chambers in second whorl	10	21–24
Number of chambers in third whorl	13	31–34
Number of chambers in final whorl	50	13–41
Proloculus internal diameter	?	0.15–0.32 mm

REMARKS. These specimens generally have only lightly developed bars covering the retral processes, and the very low chambers have their sutures so close together that double rows of pores of the sutural canal give the impression that the shell is highly perforate (see Pl. 6, fig. 13). There is no external difference between the two generations and only one microspheric form has been found. The septa in this species are double, their canal opening into the subsutural canal which branches near the surface to give biperforate sutural pores. The umbilical canals seldom anastomose and some appear to arise from a poorly-developed spiral canal. The plug is poorly developed for *E. adelaidense* but as other morphological details are very similar, we consider that the Togopi specimens are conspecific. *Elphidium rotatum* Howchin & Parr (1938: 299; pl. 17, figs 1, 2, 4), a much compressed form, recorded from the Pliocene to Recent of Australia, appears to be the only other species in the Indo-Pacific similar in size and external morphology to our material.

DISTRIBUTION. *Cellanthus adelaidensis* does not appear to have been found later than the Pliocene. Howchin & Parr (1938) record it from the Miocene and Upper Pliocene of South Australia, while Billman & Kartaadipura (1975: 306) state that in east Kalimantan, Borneo, their *Elphidium* sp. 14 'has its highest stratigraphical occurrence in the *Asanoina* Zone', which they interpret as Pliocene.

Cellanthus biperforatus sp. nov.

Fig. 61; Pl. 7, figs 3a, b; Pl. 10, fig. 21

DIAGNOSIS. A rotund *Cellanthus* with a large canaliculate plug. Sutures straight to gently curved, bearing on either side a row of sutural pits.

NAME. From the two rows of sutural pits, one on each side of the suture.

HOLOTYPE. BM(NH) reg. no. P50160, from NB 9452.

MATERIAL. 90 specimens. NB 9446, 9447, 9452, 9454, 9456/7, 9460.

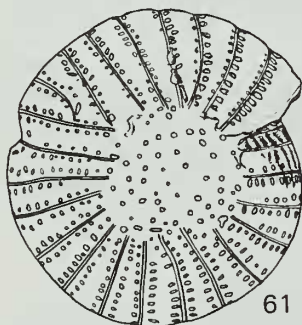


Fig. 61 *Cellanthus biperforatus* sp. nov. P50160. Side view of holotype showing position of chamber sutures (see also Pl. 7, figs 3a, b). Sample NB 9452. $\times 40$.

DESCRIPTION (Holotype). Test calcareous, perforate, biconvex and plugged. Plug raised, translucent, occupying a third of the test diameter and perforated by many canals. Periphery round in side view. Last whorl involute, made up of 24 non-lobate chambers with sutures which are radial to gently curved (slightly depressed in later chambers) and lined on each side by a row of pits containing the surface pores of the subsutural canal system. On the later-formed sutures the anterior pores are larger than the posterior row, but for the most part are of the same size. Test inflated in apertural view, peripheries subrounded. Apertural face low, aperture a row of 13 interiomarginal pores separated from each other by bars of secondary shell material which are developed on earlier whorls and extend in a subdued manner onto the first few chambers of the last whorl.

DIMENSIONS (Holotype). Maximum diameter 1.06 mm, thickness 0.65 mm, diameter of plug 0.45 mm.

VARIATION. Size range of paratypes: maximum diameter 0.32–1.40 mm, thickness 0.30–1.05 mm, plug diameter 0.40–1.15 mm.

Externally the two generations are not distinguishable. From sectioned megalospheric specimens the following chamber counts were made:

Chambers in first whorl	6–14
Chambers in second whorl	8–23
Chambers in third whorl	13–32
Chambers in last whorl	24–42

A maximum of six whorls has been counted in this species.

REMARKS. Our specimens superficially resemble the Neogene species *Elphidium taiwanum* Nakamura (1937: 139; pl. 11, figs 9a, b) and *E. javanum* Yabe & Asano (1937: 102; pl. 18, figs 10a, b), but differ in possessing on each side of the suture a row of sutural pits, each containing a pore which forms the surface extremity of the subsutural canal system. In the last two species, which are similar to *Cellanthus craticulatus* (Fichtel & Moll) except for their subdued retral ornament, the bifurcating subsutural canal reaches the surface of the test as pores in a single row of elongate sutural pits.

The very thin double septum, double sutural pores and large perforate plug are typical of *Cellanthus*.

Cellanthus hailei sp. nov.

Pl. 6, figs 9a, b; Pl. 10, fig. 22

DIAGNOSIS. An inflated *Cellanthus* with rounded peripheries, low apertural face and apparently poreless plug. Ornament of many retral bars per suture; those at the beginning of the final whorl anastomosing to give coarse striae.

NAME. In honour of Professor N. S. Haile, formerly of the Geological Survey of Malaysia, who collected the material described in this paper.

HOLOTYPE. BM(NH) reg. no. P50152, from NB 9452.

MATERIAL. 30 specimens. NB 9447, 9449, 9452, 9453, 9460.

DESCRIPTION (Holotype). Test round in outline, involute, margin entire; inflated and subovate in edge view, peripheries subrounded. There are 36 chambers in the final whorl with 10 retral bars per suture on each side on the first, and 21 on the last chamber of the whorl. The retral bars tend to branch and anastomose at the beginning of the final whorl to give crude striae, but are distinctly separate from the next row of bars after about 10 chambers. Sutures gently curved and slightly limbate later. Umbilical plug distinct and raised but feebly dissected; one or two pits are present but there seem to be no true pores. Apertural face low, aperture indistinct, probably a series of interiomarginal pores.

DIMENSIONS (Holotype). Maximum diameter 1.40 mm, thickness 0.84 mm. Height of apertural face 0.09 mm. Diameter of plug 0.40 mm.

VARIATION. Size range of paratypes: diameter 0.40–1.50 mm, thickness 0.70–1.05 mm. Diameter of plug 0.18–0.45 mm. The number of retral bars per suture on each side of the test varies from 6 to 20, the number of whorls from 3 to 6 and the number of chambers per whorl as seen in section is as follows:

	<i>Microspheric</i>	<i>Megalospheric</i>
First whorl	7	10–14
Second whorl	10–11	23–27
Last whorl	28–34	25–40

The internal proloculus diameter is 0.01 mm in the microspheric form and between 0.13 and 0.22 mm in the megalospheric.

REMARKS. In both generations, determinable only in thin section, the coiling is tight with little increase in the chamber width throughout. The septa are double and carry a broad canal which opens as a rectangular single pore at the surface. This canal system does not penetrate the wedge-shaped plug, which is composed of numerous laminated layers and causes offlap of the newly formed chambers (see Pl. 10, fig. 22). The presence of a double septum places our new species in *Cellanthus*, but the apparent absence of umbilical canals and double sutural pores is inconsistent with the classification (Loeblich & Tappan 1964) used here. The aperture, often seen best in vertical thin sections, is a single row of large interiomarginal pores.

Cellanthus hailei sp. nov. has the striate ornamentation of the early chambers of the final whorl so characteristic of the *Elphidium indicum/hispidulum* group, together with the general test morphology of *Cellanthus craticulatus* to which it is most closely related. It differs from *C. craticulatus* (and *E. batavum* Hofker), however, in possessing a non-perforate plug and a partially striate test; furthermore, it does not have a keel.

Genus *CRIBROELPHIDIUM* Cushman & Brönnimann, 1948

Type-species: *Criboelphidium vadesens* Cushman & Brönnimann, 1948.

Criboelphidium dentense sp. nov.

Pl. 7, figs 4a, b

DIAGNOSIS. A robust *Criboelphidium* with inflated later chambers and keeled only in the earlier part of the last whorl. Pustulose septal pits strongly developed and elongate in later part of test; up to 14 septal bars per suture on each side. Apertural face very broad.

NAME. Described from the Dent Peninsula, Sabah.

HOLOTYPE. BM(NH) reg. no. P50161, from NB 9452.

MATERIAL. 64 specimens. NB 9452.

DESCRIPTION (Holotype). Test involute, perforate, periphery in side view smoothly curved in early part of final whorl, becoming slightly lobate later. Chambers, 11 in number, only gradually increasing in size; early chambers keeled, later ones unkeeled and moderately inflated. Sutures curved, depressed and crossed by strong bars of shell material which in the later chambers do not completely bridge the sutures; between the bars are septal pits (fossettes), the floors of which are finely pustulate. Umbilical region slightly depressed with a faintly rugose plug associated in the earlier portion of the final whorl with the thickened umbilical ends of the chambers. In apertural view the test is moderately compressed, the periphery of the earlier part of the final whorl being subrounded, that of the apertural face broadly rounded. Apertural face convex, almost as high as wide, with distinct basal interiomarginal pores separated by bars; small areal pores surrounded by pustules are also present.

DIMENSIONS (Holotype). Maximum diameter 0.50 mm, thickness at centre 0.21 mm. Height of apertural face 0.21 mm, width 0.28 mm.

VARIATION. Size range of paratypes: maximum diameter 0.33–0.70 mm, thickness across last chamber 0.33–0.70 mm, thickness across umbilicus 0.15–0.35 mm. The number of chambers in the first whorl varies between 6 and 9, those in the last whorl between 10 and 11. Since the initial part of the coil is tight there is no way of distinguishing the two generations externally.

REMARKS. Closely related to the *Elphidium articulatum/excavatum* group, but differs in its less lobate periphery, partial development of a keel, more numerous fossettes, more inflated test and much wider apertural face. The new species also resembles in side view *Elphidium kusiroense* Asano from the Pleistocene of Japan (Asano 1938: 590; pl. 14, fig. 2), but in apertural view is markedly different – the latter is very compressed and does not have a keel on the early part of the final whorl.

Because of the absence of a well-defined canal system, presence of sutural bars, single septa and both interiomarginal and areal pores on the apertural face, the species is placed in *Criboelphidium*.

Genus *CRIBRONONION* Thalmann, 1947

Type-species: *Nonionina heteropora* Egger, 1857.

Cribrononion reticulosus (Cushman)

Pl. 6, fig. 12

1933 *Elphidium reticulosum* Cushman: 51; pl. 12, figs 5a, b.

1939 *Elphidium reticulosum* Cushman; Cushman: 59; pl. 16, figs 24a, b.

? 1957 *Elphidium hyalocostatum* Todd: 300; pl. 88, figs 19a, b.

1969 *Elphidium* sp. A cf. *E. milletti* (Heron-Allen & Earland); Betjeman: 130; pl. 18, figs 8, 9.

1970 *Elphidium reticulosum* Cushman; Matoba: 52; pl. 6, figs 12a, b.

? 1970 *Elphidium* cf. *reticulosum* Cushman; Matoba: 52; pl. 6, figs 13a, b.

MATERIAL. 70 specimens. NB 9447, 9449, 9450, 9452, 9454.

VARIATION. Maximum diameter 0.30–0.58 mm, maximum thickness 0.15–0.23 mm. Number of chambers in first whorl 7–9, in second 8–13 and in final whorl 9–12.

REMARKS. A tightly coiled, somewhat compressed species with retral bars strongly developed on the earlier chambers, the final chambers being covered with 'a fine network of irregular pattern'

as described by Cushman (1933: 51). The plug area consists of plates (or layers) of crystalline material; no canals are visible. The later chambers of a number of specimens in the Togopi samples have a tendency to become strongly inflated as in the type-figure, but our illustrated specimen (Pl. 6, fig. 12) is more usual. Internally there are no diverging canals emanating from the intraseptal subsutural canal system. The aperture on the final chamber is a series of pores at the base of the apertural face; on earlier chambers it appears as an interiomarginal slit. These characters signify *Cribrononion*.

Forms very close to *Elphidium hyalocostatum* Todd occur in our samples and these would seem to be no more than a variety of *E. reticulosum* with stronger and more aligned ornamentation on the final chambers. We have examined the types of *E. milletti* (Heron-Allen & Earland) and note that they include specimens distinct from Cushman's species. The characteristic chevron ornament is particularly well developed on later chambers, and the periphery is strongly lobate when seen in side view (see Heron-Allen & Earland 1915: 735; pl. 53, figs 38–42). Murray's *E. reticulosum* from the Persian Gulf (1970: fig. 9C) would appear to belong to *E. milletti*.

DISTRIBUTION. Previously found only in the Recent of Japan (Matoba 1970), Saipan (Todd 1957), Tonga (Cushman 1933, 1939) and Western Australia (Betjeman 1969).

***Cribrononion tikotoensis* (Nakamura)**

Pl. 6, figs 10a, b

1937 *Elphidium tikotoensis* Nakamura: 139; pl. 11, figs 10a, b.

1962 *Elphidium tikotoensis* Nakamura; Huang: 194; pl. 1, figs 1, 4b.

? 1967 *Cellanthus tungliangensis* Huang: 137; pl. 1, figs 1a, b; pl. 2, figs 2a, b.

1968 *Cellanthus tikotoensis* (Nakamura) Huang: 88; pl. 4, fig. 1.

MATERIAL. 54 specimens. NB 9450, 9452, 9454, 9460.

VARIATION. Maximum diameter 0.32–0.62 mm, thickness 0.18–0.25 mm. Number of chambers in first, second and final whorls 6–8, 9–12 and 11–15, respectively. Internal proloculus diameter 0.03–0.04 mm.

REMARKS. The umbilical region of our specimens is usually surrounded by enlarged sutural pores and the plug is variously developed, sometimes covered by secondary granulate shell material and often so reduced that the test appears evolute. The presence of interiomarginal pores and the simple canal system place it in *Cribrononion*. Nakamura's type-figure shows, however, a narrow interiomarginal slit-like aperture, a feature which is not commented on in either of Huang's redescrptions of the types (1962, 1967). *Cellanthus tungliangensis* Huang, from the Plio-Pleistocene of Penghu Island, off Taiwan, seems to differ very little from *E. tikotoensis* Nakamura; it certainly has small pores at the base of the apertural face and could well be conspecific.

DISTRIBUTION. Previously known only from the Neogene of Taiwan.

Genus *ELPHIDIELLA* Cushman, 1936

Type-species: *Polystomella arctica* Parker & Jones in Brady, 1864.

***Elphidiella indopacifica* Germeraad**

Pl. 7, figs 5–7; Pl. 10, fig. 20

1946 *Elphidiella indopacifica* Germeraad: 67; pl. 3, figs 3, 4.

MATERIAL. 205 specimens. NB 9446, 9447, 9450, 9452, 9454, 9460.

VARIATION. Maximum diameter 0.41–1.45 mm, thickness 0.20–0.80 mm. Number of chambers in first whorl 7–9, in second 9–12 and in last whorl 9–26.

REMARKS. 'Differs from all known Elphidiellas by the large number of chambers' writes Germeraad (1946) in his description of this distinctive species, which surprisingly does not appear to have been recorded since. Our larger specimens, few in number and microspheric (Pl. 7, fig. 5), agree closely with his figures both in side and apertural view.

Most of our specimens, however, are much smaller (diameter less than 0.85 mm) and those sectioned proved to be megalospheric. These tests (Pl. 7, figs 6, 7) are robust and stout, but their peripheries are more acute and the number of chambers in the final whorl never exceeds thirteen. They nevertheless show the characteristic double row of alternating pits at each suture (the anterior set is the longest) and are thus conspecific. Germeraad had only two specimens and described only the microspheric form.

Because of the double row of sutural pores, interioareal multiple apertures and lack of retral processes the species is retained in *Elphidiella* despite the absence of a well-developed canal system.

DISTRIBUTION. Germeraad (1946) recorded *E. indopacifica* from the Recent of the Island of Ceram, Indonesia.

Subfamily FAUJASININAE Bermúdez, 1953

Genus *PARRELLINA* Thalmann, 1951

Type-species: *Polystomella imperatrix* Brady, 1881.

Parrellina hispidula (Cushman)

Pl. 6, fig. 11

1936 *Elphidium hispidulum* Cushman : 83; pl. 14, figs 13a, b.

1968 *Elphidium hispidulum* Cushman; Chiji & Lopez : 106; pl. 13, fig. 3.

1968 *Elphidium hispidulum* Cushman; Chiji : 62; pl. 3, fig. 12.

1968 *Parrellina hispidula* (Cushman) Hofker : 31; pl. 11, figs 1-7.

MATERIAL. 30 specimens. NB 9446, 9447, 9450.

VARIATION. Maximum diameter 0.30-0.65 mm, thickness 0.17-0.33 mm. Number of chambers in first, second and final whorl, 6-7, 10-12 and 9-15 respectively.

REMARKS. These specimens fall within the *E. hispidulum/indicum* group and differ from *E. reticulosum* Cushman in being inflated, plugged, hispid and non-reticulate. *Elphidium hokkaidoense* Asano (1950 : 8, text-figs 44, 45) from the Pliocene of Japan is probably synonymous as it is said to differ from *E. indicum* Cushman in 'having weak costae nearly parallel to the periphery of earlier chambers', a feature also common to *E. hispidulum*. *E. indicum* has a large raised plug while *E. hispidulum* and *E. hokkaidoense* do not.

There are no true retral processes present in our specimens and in thin section the septal canal can be seen to branch within the spiral septa forming connections with more than one of the large pores traversing the wall. This type of canal system is typical of *Parrellina* (see Hofker 1968 : 31).

DISTRIBUTION. *Fossil*: Pleistocene of Japan (Chiji 1968). This range would possibly be extended back into the Pliocene if *E. hokkaidoense* Asano proved to be conspecific. *Recent*: Australia (Cushman 1936), Java (Hofker 1968) and Japan (Chiji & Lopez 1968).

Family NUMMULITIDAE de Blainville, 1825

Subfamily NUMMULITINAE de Blainville, 1825

Genus *NUMMULITES* Lamarck, 1801

Type-species: *Camerina laevigata* Bruguière, 1792.

Barnett (1974), after studying 58 species of the Nummulitidae including *Nummulites willcoxi* Heilprin, the type-species of *Operculinoides* Hanzawa, concluded that *Operculinoides* is a superfluous generic name and that *Assilina*, *Operculina* and *Operculinella* are distinct from *Nummulites*.

Nummulites cf. *amplicuneatus* (Cole)

Pl. 9, figs 6-9; Pl. 10, fig. 26

cf. 1954 *Operculinoides amplicuneata* Cole : 573; pl. 204, figs 7, 9, 17, 18.

MATERIAL. Over 270 specimens. NB 9452.

VARIATION. Maximum diameter 1.9–3.7 mm, thickness 0.9–1.6 mm. Internal proloculus diameter 0.10–0.20 mm. Number of whorls 3–4 $\frac{3}{4}$. Number of chambers in first, second and third whorls 6–7, 11–15 and 18–21 respectively.

REMARKS. Only the involute and tightly coiled megalospheric generation is present. It has an acute edge, strong marginal cord and radiate or sinuous, flush sutures. Pustules are rarely present between sutures.

Although our specimens closely resemble *Nummulites amplicuneatus* (Cole), other externally similar species are *N. bikiniensis* (Cole) and *N. rectilatus* (Cole), from the Upper Miocene and Plio-Pleistocene respectively of Bikini Atoll, though neither of these has an acute peripheral margin.

DISTRIBUTION. *N. amplicuneatus* was recorded by Cole (1954) from the uppermost Miocene of Bikini Atoll, west Pacific.

Nummulites tamanensis (Vaughan & Cole)

Pl. 9, figs 13–16; Pl. 10, fig. 25

1941 *Operculinoides tamanensis* Vaughan & Cole : 43; pl. 10, figs 9, 10; pl. 11, figs 8–10; pl. 12, figs 1–3.

MATERIAL. 128 specimens. NB 9452.

VARIATION. Diameter 2–9 mm (megalospheric form 2–5.5 mm). Thickness not exceeding 1 mm. Internal proloculus diameter: microspheric form 0.03–0.15 mm, megalospheric 0.12–0.22 mm. Number of chambers in the first whorl: 7–8 (microspheric), 5–6 (megalospheric); second whorl: 10–12 (microspheric), 10–15 (megalospheric).

REMARKS. The present specimens are complanate to lenticular in shape, the umbo usually being more prominent on one surface than the other; the slowly unwinding coil has not been observed to flare in the microspheric form. Thin sections demonstrate the presence of trabeculae-like structures, which externally can be seen only faintly in the chamber walls of complete specimens but which have been shown by scanning electron microscopy of fractured specimens to be solid and to occupy the whole thickness of the wall. These 'trabeculae', which run anteriorly, normal to the septum, and have been observed to branch and even become arborescent (Pl. 10, fig. 25), are certainly present from the third chamber onwards and may occur back to the proloculus.

Our material has been compared directly with the types of *Operculinoides tamanensis* Vaughan & Cole (USNM nos 545879, 546154–7), the only observable difference being that the proloculus in the American specimens is smaller, having an internal diameter of 0.08–0.09 mm. We know of no other post-Oligocene species of *Nummulites* from the Indo-west Pacific region which shows these characteristic 'trabeculae', the function of which is unknown.

DISTRIBUTION. Originally described from the Lower Miocene of Trinidad; it does not appear to have been recorded subsequently.

Genus *OPERCULINA*³ d'Orbigny, 1826

Type-species: *Lenticulites complanatus* DeFrance, 1822.

Van der Vlerk & Bannink (1969) suggested that the relative ages of deposits containing *Operculina* could be determined by calculating the value of 'factor E', this being a measure of the extent to which the second chamber is enclosed by the third

$$\left(\frac{\text{angle } e^1}{\text{angle } e^2} \times 100 \right).$$

³ See comments on *Nummulites*, p. 88.

They observed a significant decrease in the grade of enclosure in specimens from rocks of Eocene age through to those living today and plotted the rate of change of 'factor E' on a graph (see van der Vlerk & Bannink 1969: fig. 3).

Operculina ammonoides (Schröter) and *O. bartschi* Cushman from the Togopi Formation have been used to test this hypothesis. Our two nummulitids, *Nummulites* cf. *amplicuneatus* (Cole) and *N. tamanensis* (Vaughan & Cole), were also measured although we are aware that 'factor E' might not be applicable to them since van der Vlerk & Bannink studied only *Operculina*. Twenty good thin sections of each species, all from sample NB 9452, were measured using the prescribed method, the angles e^1 and e^2 being measured separately by both of us and the arithmetic mean calculated. Fig. 62 shows the percentage distribution of 'factor E' expressed in histograms (compare with van der Vlerk & Bannink 1969: fig. 2) and the calculated mean values for the four species. It can be seen that *O. bartschi* and *N. tamanensis* give very different and much lower results than *O. ammonoides* and *N. cf. amplicuneatus*, which although producing almost identical means, have contrasting histogram patterns.

Measurements were also made of three other species of known age and plotted (Fig. 63) together with the four Togopi species. *Operculina heberti* Munier-Chalmas (12 specimens) from

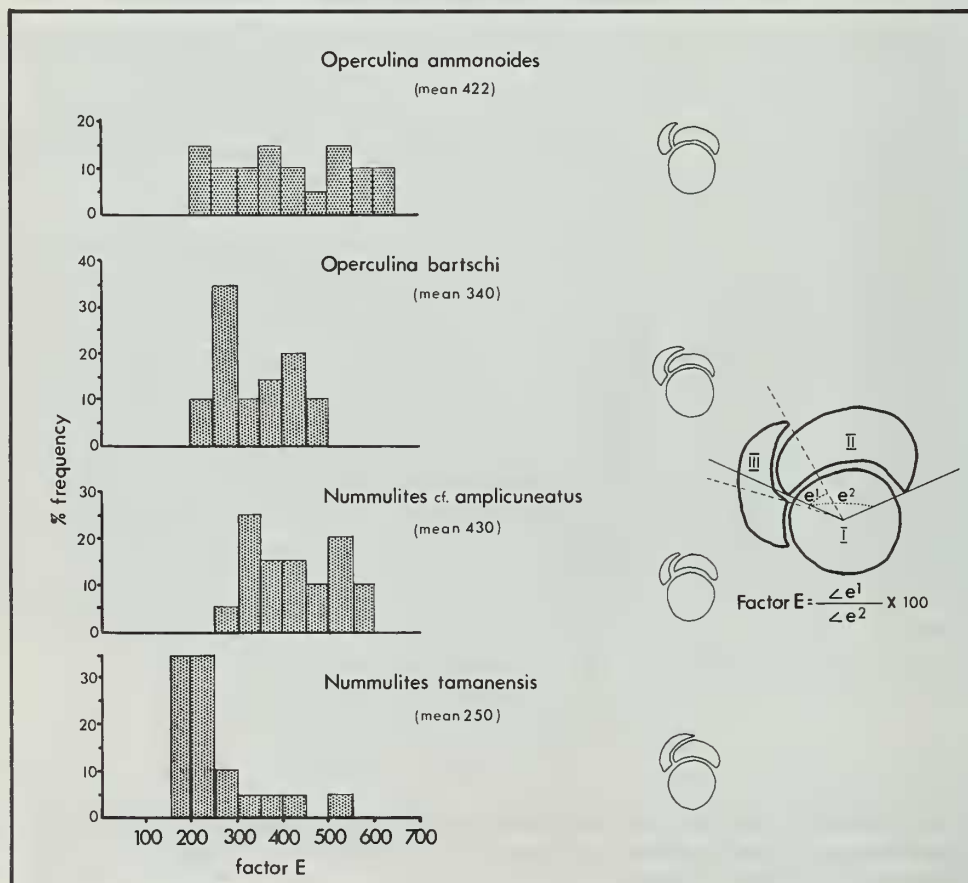


Fig. 62 Left: Percentage distribution of factor E in four species of *Operculina* and *Nummulites*, sample NB 9452, Togopi Formation. Twenty thin sections were measured in each case. Right: Method of measuring factor E from thin sections of megalospheric forms (after van der Vlerk & Bannink 1969). The degree of enclosure of chamber II by chamber III is shown for a typical member of each species to the left of this.

the Palaeocene of France gave an 'Oligocene' date, an *Operculinella* (10 specimens) from the Middle Miocene part of the Sebahat Formation (see p. 5) gave a fairly accurate result, while 11 Recent specimens of *Operculina ammonoides* (Schröter) in the Heron-Allen & Earland Collection, from Singapore Roads, produced a result slightly higher than that of van der Vlerk & Bannink's Recent species (Fig. 63). The Togopi specimens of *O. ammonoides* and *N. cf. amplicuneatus* both

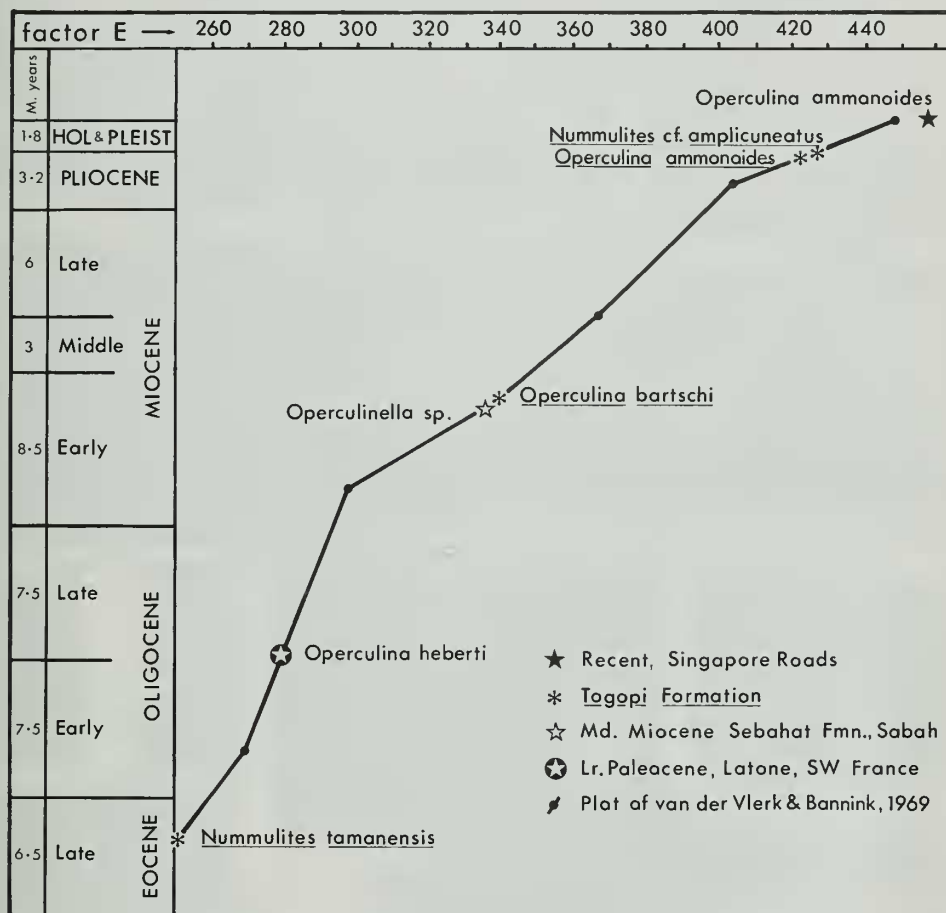


Fig. 63 The mean values of factor E for the four species of *Operculina* and *Nummulites*, together with those of three comparative species of known age, plotted on van der Vlerk & Bannink's (1969) graph of the rate of evolution of factor E but with time scale modified after Eysinga (1975). (Compare with fig. 3 of van der Vlerk & Bannink 1969.)

indicated an Upper Pliocene age; unfortunately *O. bartschi* gave an early Miocene date while *N. tamanensis* suggested a late Eocene age. This exercise did not, therefore, confirm the stratigraphical value of 'factor E' and further work is obviously necessary. It may be that the rate of evolution varies from one lineage to another, and in this connection it is noteworthy that the two tightly coiled Togopi nummulitids, although belonging to different genera, apparently produced a reliable date while the species with flaring coils did not. Unfortunately van der Vlerk & Bannink did not identify the species in their study.

Operculina ammonoides (Schröter)

Pl. 9, figs 1-5; Pl. 10, figs 23, 27

- 1781 *Nautilus ammonoides* Gronovius : 282; pl. 19, figs 5, 6.
 1783 *Nautilus ammonoides* Schröter : 21.
 1860 *Operculina* sp. Carpenter : 12; pl. 3, figs 1, 2.
 1893 *Operculina ammonoides* (Gronovius) Egger : 242; pl. 20, figs 38, 39.
 1921 *Operculina discoidalis* (d'Orbigny); Cushman : 379 (see Cole 1961 : pl. 14, fig. 1).
 1921 *Operculina granulosa* Leymerie; Cushman : 381 (see Cole 1961 : pl. 14, fig. 23).
 1924 *Operculina gaimardi* d'Orbigny; Cushman : 50; pl. 17, fig. 4.
 1925 *Operculina* (*Operculinella*) *venosa* (Fichtel & Moll); Yabe & Hanzawa : 49; pl. 5, figs 5-9, 19-27 only.
 1933 *Operculina granulosa* Leymerie (?); Cushman : 56; pl. 14, figs 1-7b; pl. 15, figs 3-6 only; pl. 16, figs 1-3.
 1935 *Operculinella venosa* (Fichtel & Moll); Hanzawa : 23; pl. 1, figs 31, 32, 34 only.
 1938 *Operculina ammonoides* (Gronovius); Chapman & Parr : 290; pl. 17, figs 12-16; text-fig. 1, no. 5.
 1939 *Operculina ammonoides* (Gronovius); Hanzawa : 229; pl. 15, figs 1a-2b only.
 1946 *Operculinella venosa* (Fichtel & Moll); Abrard : 12; pl. 1, figs 5-6.
 1948 *Operculina ammonoides* (Gronovius); Bannink : 81; pl. 5, figs 30, 31, 34-37; pl. 7, figs 46-48, 52, 53; pl. 8, figs 55, 56; pl. 11, figs 96-98; pl. 12, figs 99-101; pl. 13, figs 115-120; pl. 15, figs 133-142; pl. 17, figs 155-157, 164, 165; pl. 18, figs 168-170; pl. 19, figs 177-183.
 1949 *Operculina gaimardi* d'Orbigny; Said : 14; pl. 2, fig. 37.
 1954 *Operculina ammonoides* (Gronovius); Cushman, Todd & Post : 346; pl. 87, fig. 1.
 1959 *Operculina ammonoides* (Gronovius); Cole : 356; pl. 28, figs 4-10; pl. 29, figs 3-15; pl. 30, figs 2-6, 8 only; pl. 31, figs 5-7.
 1959 *Operculina ammonoides* (Gronovius); Graham & Militante : 76; pl. 12, figs 1, 2.
 1960 *Operculina ammonoides* (Gronovius); Smout & Eames : 110 (see Cole 1959 : pl. 29, figs 3, 7, 12; pl. 31, figs 5-7).
 1960 *Operculina hanzawai* Smout & Eames : 110 (see Cole 1959 : pl. 29, fig. 9).
 1960 *Operculinella venosa* (Fichtel & Moll); Smout & Eames : 111 (see Cole 1959 : pl. 28, figs 8, 9; pl. 29, figs 6, 8, 10; pl. 30, figs 2, 6, 8).
 1961 *Camerina ammonoides* (Gronovius) Cole : 118; pl. 14, figs 1-17, 20, 22-24 only; pl. 15, figs 2-6, 11 only.
 1961 *Operculina ammonoides* (Gronovius); Huang : 86; pl. 3, figs 22, 23.
 1964 *Operculina ammonoides* (Gronovius); Rocha & Ubaldo : 156; pl. 19, fig. 13.

MATERIAL. Over 220 specimens. NB 9447, 9449, 9450, 9452, 9453, 9454, 9460.

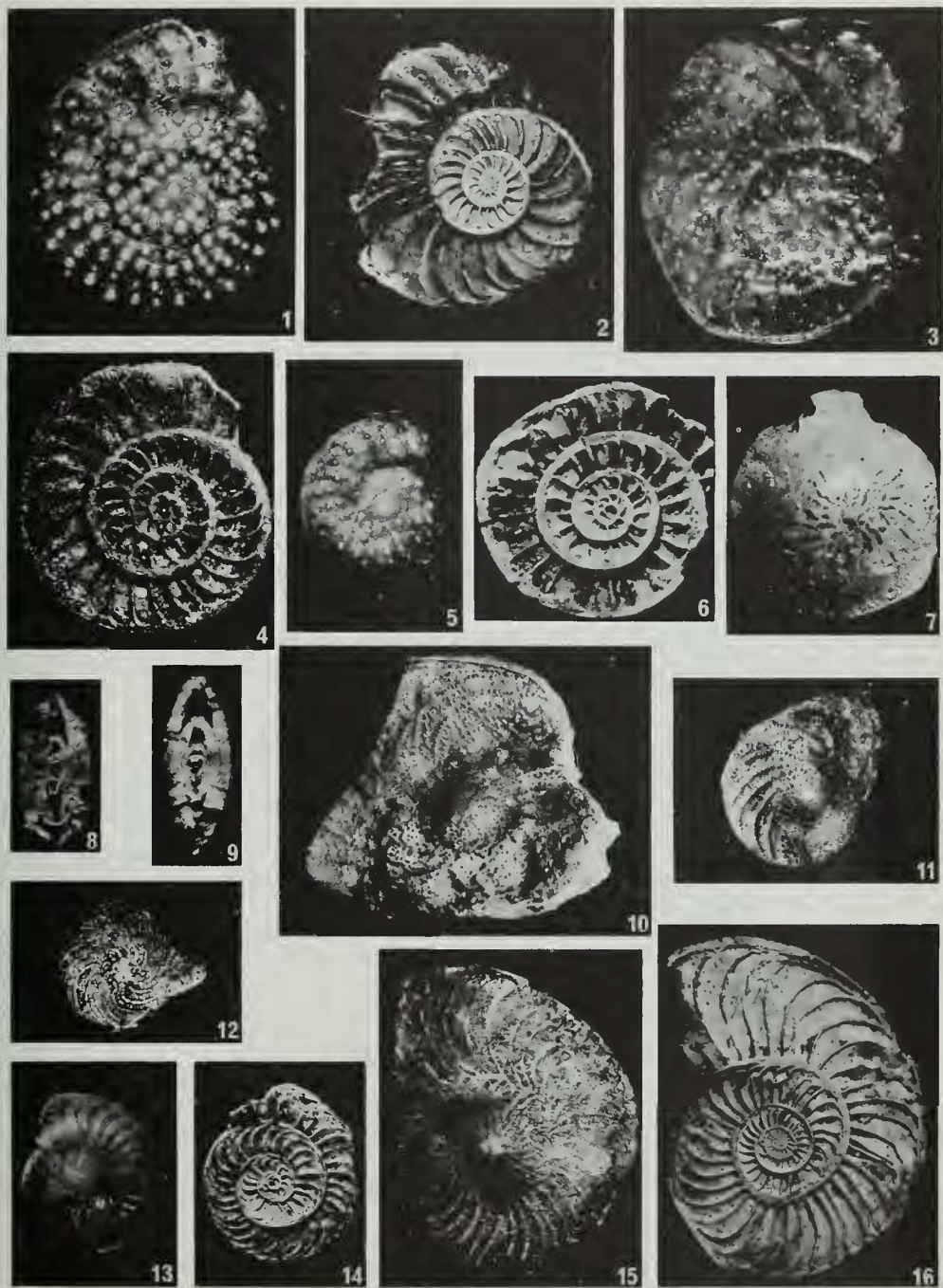
VARIATION.

	<i>Microspheric forms</i>	<i>Megalospheric forms</i>
Maximum diameter	3-5 mm	0.6-3 mm
Thickness	up to 0.72 mm	0.25-0.65 mm
Internal proloculus diameter	0.02-0.03 mm	0.05-0.11 mm
Number of chambers in first whorl	5-7	6-8
Number of chambers in second whorl	10-12	9-13

Plate 9

Light microscopy, magnifications approximate

- Figs 1-5 *Operculina ammonoides* (Schröter). Figs 1, 5, P50194, P50198. Megalospheric forms, external views. Fig. 4, P50197. Megalospheric form, horizontally split specimen. Fig. 2, P50195. Microspheric form, horizontally split specimen. Fig. 3, P50196. Microspheric form, external view. All from sample NB 9452. $\times 15$.
 Figs 6-9 *Nummulites* cf. *amplicuneatus* (Cole). Megalospheric forms. Figs 6, 7, P50199, P50200. Horizontally split specimen and external view of test. Figs 8, 9, P50201, P50202. Block half-sections (vertical). All from sample NB 9452. $\times 10$.
 Figs 10-12 *Operculina bartschi* Cushman. External views. Fig. 10, P50203. Microspheric form. Figs 11, 12, P50204, P50205. ? Megalospheric forms. All from sample NB 9452. $\times 6$.
 Figs 13-16 *Nummulites tamanensis* (Vaughan & Cole). Figs 13, 14, P50206, P50207. Megalospheric forms; external view of test and horizontally split specimen. In Fig. 13 the 'trabeculae' characteristic of this species can just be seen externally, running normal to the later-formed sutures. Figs 15, 16, P50208. Microspheric form; external view of one half of test and internal view of other half, horizontally split. All from sample NB 9452. $\times 6$.



REMARKS. This species was first described and figured by Gronovius (1781), but following Hemming (1954 : 283) the diagnosis of *Nautilus ammonoides* given by Schröter in 1783 is now taken as the first valid description, Gronovius' rather poorly illustrated specimens being the types. The inadequate description and illustrations have caused much confusion, and for many years *Hyalinea balthica* (Schröter) was regarded as *O. ammonoides*. Chapman & Parr (1938), Carter (1953), Smout & Eames (1960) and Cole (1959, 1961) all redefined the species, but there still remains great difficulty in setting a limit on intraspecific variation, which is doubtless governed by ecological factors. Cole and Smout & Eames disagree on whether there is a continuous variation between evolute and involute tests and on what constitutes *Operculinella venosa* (Fichtel & Moll). However, as these protagonists agree with Chapman & Parr's (1938) redefinition, we base our identification of *Operculina ammonoides* primarily on the latter's diagnosis.

The numerous specimens in Togopi sample NB 9452 show gradation from thin, almost evolute tests (supposedly mature) with a strong marginal cord, to thick, nearly involute immature tests, but never to completely involute '*Operculinella venosa*'-like forms. The megalospheric generation remains close-coiled but the microspheric has a flared last whorl (see Pl. 9). Both generations have a coarsely pustulate umbilical area with a large central umbonal pustule. In the final whorl, coarse beading commonly occurs on chambers or sutures, or both, being occasionally restricted to the chambers only, or to the early sutures.

The morphotypes represented by the following have not been seen in our material and are not, therefore, included in our synonymy, although regarded by some authors as synonymous with *O. ammonoides*.

Operculinella venosa (Fichtel & Moll); Cushman 1924.

? *Operculina ammonoides* (Gronovius); Carter 1953 : pl. 34, figs 4-6.

Operculina elegans Cushman 1921 : pl. 97, fig. 3.

Operculina discoidalis (d'Orbigny) var. *involuta* Cushman, 1921.

Nummulina discoidalis d'Orbigny, 1826.

Assilina nitida d'Orbigny, 1826.

Operculina gaymardi d'Orbigny, 1826.

Operculina gaimardi d'Orbigny; Cushman 1933 : pl. 13, figs 1-5.

Operculina philippinensis Cushman; Yabe & Hanzawa 1930 : pl. 12, fig. 9.

Operculina ammonoides (Gronovius); Chiji & Lopez 1968 : pl. 13, fig. 10.

Operculina sp. Puri 1957 : pl. 13, figs 1-14.

Operculinoides sp. Puri 1957 : pl. 13, figs 5-8.

Those specimens renamed by Barker (1960 : pl. 112) as *Operculina ammonoides* from Brady (1884).

DISTRIBUTION. *Fossil*: Miocene (Tf) of Borneo (Cole 1959); Neogene of Okinawa and Taiwan (Hanzawa 1935); post-Pliocene of Okinawa (Yabe & Hanzawa 1925, Cole 1959); ? Pleistocene of the Ryukyus (Cole 1959); Quaternary of the New Hebrides (Abrard 1946) and Timor (Rocha & Ubaldo 1964). Bannink (1948) records this species from numerous borings in Indonesia of Miocene age and younger. *Recent*: Widespread in the Indian and Pacific Oceans, the Red Sea and the Persian Gulf.

Operculina bartschi Cushman

Pl. 9, figs 10-12; Pl. 10, fig. 24

1860 *Operculina* sp. Carpenter : 12; pl. 3, figs 6, 11, 12 only; pl. 4, figs 1-4, 6, 10, 11.

1901 *Operculina* sp. Yoshiwara : pl. 1, figs 1, 2.

1921 *Operculina bartschi* Cushman : 376, text-fig. 13.

1925 *Operculina bartschi* Cushman var. *punctata* Yabe & Hanzawa : 52; pl. 6, figs 13-15; pl. 7, figs 13-18.

1925 *Operculina bartschi* Cushman; Yabe & Hanzawa : 52; pl. 6, figs 6-12; pl. 7, figs 11, 12.

1935 *Operculina bartschi* Cushman; Hanzawa : 22; pl. 2, figs 1-12.

1938 *Operculina bartschi* Cushman; Chapman & Parr : 292; pl. 17, figs 17, 18 only; text-fig. 6.

1946 *Operculina bartschi* Cushman; Abrard : 99; pl. 1, figs 3, 4.

1959 *Operculina bartschi* Cushman; Cole : 360; pl. 28, fig. 16.

MATERIAL. Over 260 specimens. NB 9450, 9452.

VARIAION.	<i>Microspheric forms</i>	<i>Megalospheric forms</i>
Maximum diameter	3-9 mm	3-6 mm
Thickness	up to 1 mm	up to 1 mm
Proloculus (internal) diameter	0.02 mm	0.11-0.25 mm
Number of chambers in first whorl	6-7	4-7
Number of chambers in second whorl	9-11	10-13
Number of chambers in third whorl	23-37	14-25

REMARKS. The chambers are high and narrow (sometimes malformed), arcuate and often sharply recurved at the periphery. The umbonal region is usually raised and invariably pustulate. Beading in both generations is heavy at the start of the last whorl, less so on later chambers; it may be light, arranged as a single row, in alternating rows or scattered over the surface; it is usually clearly separate from the sutural beads which may be isolated or fused to form bars. Smooth forms are rare.

Cushman (1921) clearly states in his type-description that this species has granulate chamber walls and no sutural beading, but as the type came from a sample containing few specimens, variation in ornament is not discussed. In *O. bartschi* var. *ornata* Cushman (1921) the granules are absent, at least on the later chambers, and only the septa are beaded, while in *O. bartschi* var. *punctata* Yabe & Hanzawa there is beading between the chambers and apparently some on the septa. Hanzawa (1935: 23) concluded that the varieties of *O. bartschi* probably intergrade, and after consulting Yabe withdrew their varietal name *punctata*, believing, correctly in our opinion, that their specimens were all conspecific with Cushman's type. The affinities of the variety *ornata*, however, remain problematical as it is difficult to differentiate it externally from *Operculina gaymardi* d'Orbigny and *O. complanata* (Defrance), and for this reason it is excluded from our synonymy. For additional information on *O. bartschi* see Cole (1961: 120).

DISTRIBUTION. *Fossil*: Miocene to Quaternary of the Ryukyu Islands (Yabe & Hanzawa 1925, Hanzawa 1935); Quaternary of the Ryukyus (Yoshiwara 1901) and the New Hebrides (Abrard 1946). *Recent*: Found in the tropical East Indies from the Philippines to Australia.

Subfamily **CYCLOCYPEINAE** Bütschli, 1880

Genus **HETEROSTEGINA** d'Orbigny, 1826

Type-species: *Heterostegina depressa* Parker, Jones & Brady, 1865.

Heterostegina sp.

Pl. 8, figs 9, 10

MATERIAL. 6 specimens. NB 9452.

VARIATION. Length c. 1.00-4.50 mm, width c. 1.00-4.00 mm, thickness c. 0.30-0.40 mm (lowest measurement on broken specimen). Proloculus (internal) diameter 0.08-0.11 mm. Number of chambers in first and second whorls respectively $4\frac{1}{2}$ -5 and $9\frac{1}{2}$ -12.

Chamber number:	1	2	3	4	5	6	7	8
Number of chamberlets:	undivided		0-2	2-4	3-5	2-3	3-5	3-4

REMARKS. There is heavy beading on the chamber sutures with small beads running parallel to each suture down each chamber as in *H. pusillumbonata* Cole. The chamberlets of the neanic portion, however, are much longer than high, as in *H. operculinoides* Hofker.

Family **HANTKENINIDAE** Cushman, 1927

Subfamily **HASTIGERININAE** Bolli, Loeblich & Tappan, 1957

Genus **HASTIGERINA** Thomson in Murray, 1876

Type-species: *Hastigerina murrayi* Thomson, 1876 (= *Nonionina pelagica* d'Orbigny, 1839).

Hastigerina siphonifera (d'Orbigny)

Pl. 8, fig. 17

1839 *Globigerina siphonifera* d'Orbigny : 83; pl. 4, figs 15–18.1960 *Hastigerina* (*Hastigerina*) *siphonifera* (d'Orbigny) Banner & Blow : 22, text-figs 2a–c (lectotype), 3a, b.

MATERIAL. 1 immature specimen. NB 9460.

DIMENSIONS OF FIGURED SPECIMEN. Greatest diameter 0.26 mm, thickness 0.20 mm.

RANGE. Recorded by Blow (1969) as *Hastigerina* (*Hastigerina*) *siphonifera* (d'Orbigny) with an age range of Middle Miocene to Recent (Zone N12–Zone N23).

Family GLOBIGERINIDAE Carpenter, Parker & Jones, 1862

Subfamily GLOBIGERININAE d'Orbigny, 1826

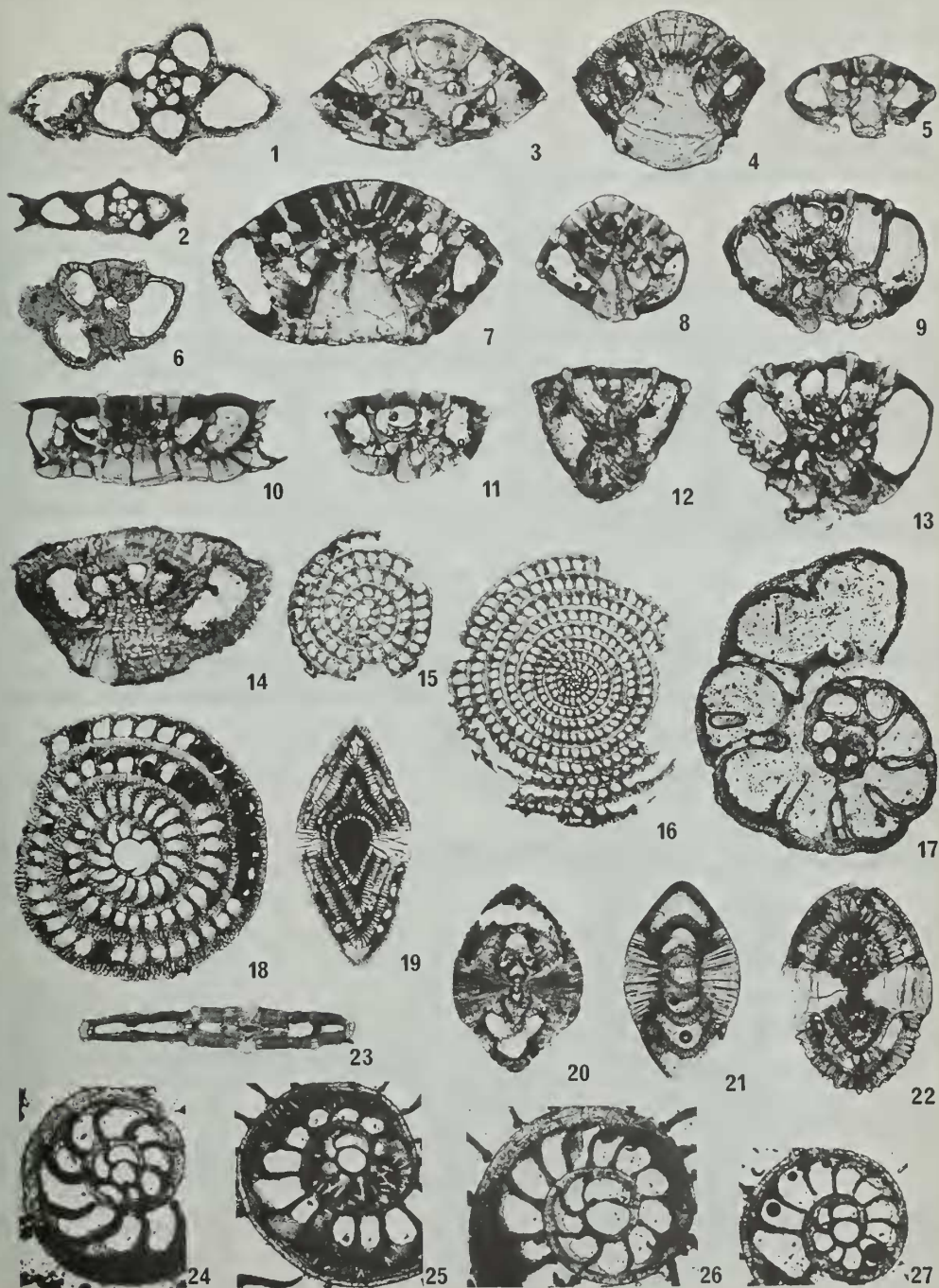
Genus GLOBIGERINA d'Orbigny, 1826

Type-species: *Globigerina bulloides* d'Orbigny, 1826.

Plate 10

Thin sections by ordinary transmitted light

Fig. 1 *Pseudomassilina medioelata* sp. nov. P50209. Vertical section. Paratype, sample NB 9452. $\times 50$.Fig. 2 *Pseudomassilina australis* (Cushman). P50210. Vertical section (final chamber broken). Sample NB 9452. $\times 50$.Fig. 3 *Asterorotalia inspinosa* Huang. P50211. Vertical section. Sample NB 9450. $\times 60$.Figs 4, 5 *Ammonia togopiensis* sp. nov. Vertical sections. Fig. 1, P50212. Microspheric form (final chamber broken). Paratype, sample NB 9452. Fig. 5, P50213. Megalospheric form. Paratype, sample NB 9449. Both specimens $\times 25$.Fig. 6 '*Schackoinella*' *globosa* (Millett). P50214. Vertical section. Sample NB 9447. $\times 110$.Figs 7–9 *Pseudorotalia indopacifica* (Thalmann). Vertical sections. Fig. 7, P50215. Microspheric form. Sample NB 9460. Fig. 8, P50126. Highly trochoid megalospheric form (trending towards *Rotalia alveiformis* Thalmann). Sample NB 9460. Fig. 9, P50217. Megalospheric form. Sample NB 9449. All specimens $\times 25$.Figs 10, 11 *Pseudorotalia catilliformis* (Thalmann). Vertical sections. Fig. 10, P50218. Microspheric form (final chamber broken). Sample NB 9456/7. Fig. 11, P50219. Megalospheric form. Sample NB 9454. $\times 20$.Figs 12, 13 *Pseudorotalia schroeteriana* (Parker & Jones). Vertical sections. Fig. 12, P50220. Immature megalospheric specimen (cf. *Gyroidina conoides* d'Orbigny). Sample NB 9452. $\times 40$.Fig. 13, P50221. Adult megalospheric specimen; the test has outgrown the conical shape. Sample NB 9449. $\times 30$.Fig. 14 *Calcarina hispida* Brady. P50222. Vertical section. Sample NB 9450. $\times 40$.Figs 15, 16 *Cellanthus craticulatus* (Fichtel & Moll). P50223, P50224. Equatorial sections of megalospheric and microspheric forms. Sample NB 9452. Fig. 15, $\times 20$; fig. 16, $\times 12$.Fig. 17 *Epistomaroides polystomelloides* (Parker & Jones). P50225. Off-centre equatorial section. Sample NB 9450. $\times 40$.Figs 18, 19 *Cellanthus adelaidensis* (Howchin & Parr). P50226, P50227. Equatorial and axial sections. Sample NB 9449. $\times 20$.Fig. 20 *Elphidiella indopacifica* Germeraad. P50228. Axial section. Sample NB 9449. $\times 25$.Fig. 21 *Cellanthus biperforatus* sp. nov. P50229. Axial section. Paratype, sample NB 9454. $\times 25$.Fig. 22 *Cellanthus hailei* sp. nov. P50230. Axial section; note the poreless plug. Paratype, sample NB 9460. $\times 25$.Figs 23, 27 *Operculina ammonoides* (Schröter). Fig. 23, P50231. Vertical section. Sample NB 9452. $\times 15$. Fig. 27, P50232. Equatorial section, early part of coil. Sample NB 9452. $\times 40$.Fig. 24 *Operculina bartschi* Cushman. P50233. Equatorial section, early part of coil. Sample NB 9452. $\times 40$.Fig. 25 *Nummulites tamanensis* (Vaughan & Cole). P50234. Equatorial section, early part of coil. Note characteristic 'trabeculae' in spiral sheet. Sample NB 9452. $\times 17$.Fig. 26 *Nummulites* cf. *amplicuneatus* (Cole). P50235. Equatorial section, early part of coil. Sample NB 9452. $\times 40$.



Globigerina bulloides d'Orbigny

Pl. 8, fig. 14

1826 *Globigerina bulloides* d'Orbigny : 277, no. 1; modèle 76.1960a *Globigerina bulloides* d'Orbigny; Banner & Blow : 3; pl. 1, figs 1a-c (lectotype), 4a-c.

MATERIAL. 1 specimen. NB 9450.

DIMENSIONS OF FIGURED SPECIMEN. Greatest diameter 0.20 mm, thickness 0.13 mm.

RANGE. Recorded by Blow (1969) as *Globigerina bulloides bulloides* d'Orbigny with a range of late Miocene to Recent (Zone N16-Zone N23).*Globigerina quinqueloba* Natland

Pl. 8, fig. 12

1938 *Globigerina quinqueloba* Natland : 149; pl. 6, fig. 7.

MATERIAL. 5 specimens (mostly with final chamber missing). NB 9447.

DIMENSIONS OF FIGURED SPECIMEN. Greatest diameter 0.20 mm, thickness 0.15 mm.

RANGE. Recorded by Blow (1969) as *Turborotalita quinqueloba* (Natland) with a range of late Miocene to Recent (Zone N17-Zone N23).Genus *GLOBIGERINOIDES* Cushman, 1927Type-species: *Globigerina rubra* d'Orbigny in de la Sagra, 1839.*Globigerinoides ruber* (d'Orbigny)

Pl. 8, fig. 15

1839 *Globigerina rubra* d'Orbigny : 82; pl. 4, figs 12-14.1960a *Globigerina rubra* d'Orbigny; Banner & Blow : 19; pl. 3, figs 8a, b (lectotype).

MATERIAL. 4 immature specimens. NB 9449, 9454.

DIMENSIONS OF FIGURED SPECIMEN. Greatest diameter 0.36 mm, thickness 0.25 mm.

RANGE. Blow (1969) gives the range of *Globigerinoides ruber* (d'Orbigny) as late Miocene to Recent (Zone N16-Zone N23).*Globigerinoides sacculifer* (Brady)

Pl. 8, fig. 16

1877 *Globigerina sacculifera* Brady : 535 (description).1884 *Globigerina sacculifera* Brady; Brady : 604; pl. 80, figs 11-17; pl. 82, fig. 4 (figures).1960a *Globigerina sacculifera* Brady; Banner & Blow : 21; pl. 4, figs 1a, b (lectotype), 2a, b.

MATERIAL. 1 immature specimen. NB 9460.

DIMENSIONS OF FIGURED SPECIMEN. Greatest diameter 0.21 mm, thickness 0.15 mm.

RANGE. Recorded by Blow (1969) as *Globigerinoides quadrilobatus sacculifer* (Brady) *forma typica* (lectotypic form), with a range of early Miocene to Recent (Zone N6-Zone N23).

Subfamily CATAPSYDRACINAE Bolli, Loeblich & Tappan, 1957

Genus *GLOBIGERINITA* Brönnimann, 1951Type-species: *Globigerinita naparimaensis* Brönnimann, 1951.*Globigerinita glutinata* (Egger)

Pl. 8, fig. 13

1893 *Globigerina glutinata* Egger : 371; pl. 13, figs 19-21.

MATERIAL. 9 specimens (characteristic bulla usually broken off). NB 9449.

DIMENSIONS OF FIGURED SPECIMEN. Greatest diameter 0.17 mm, thickness 0.13 mm.

RANGE. Recorded by F. L. Parker (1967) as *Globigerinita glutinata* (Egger) with a range of late Miocene to Recent (Zone N16–Zone N23).

Family **EPONIDIDAE** Hofker, 1951

Genus **POROEPONIDES** Cushman, 1944

Type-species: *Rosalina lateralis* Terquem, 1878.

***Poroeponides lateralis* (Terquem)**

Pl. 7, fig. 12

- 1878 *Rosalina lateralis* Terquem : 25; pl. 7 (2), figs 11a–c.
- 1884 *Pulvinulina lateralis* (Terquem) Brady : 689; pl. 106, figs 2a–3c.
- 1915 *Pulvinulina lateralis* (Terquem); Heron-Allen & Earland : 714; pl. 53, figs 6–11.
- 1921 *Pulvinulina lateralis* (Terquem); Cushman : 336; pl. 69, figs 2a–c.
- 1949 *Poroeponides lateralis* (Terquem) Said : 36; pl. 4, fig. 3.
- 1951d *Poroeponides lateralis* (Terquem); Asano : 18, text-figs 136, 137.
- 1956 *Poroeponides lateralis* (Terquem); Bhatia : 23; pl. 3, figs 3, 4, 5a–c.
- 1959 *Poroeponides lateralis* (Terquem); Graham & Militante : 96; pl. 14, figs 9a–c.
- 1960 *Poroeponides lateralis* (Terquem); Barker : 218; pl. 106, figs 2a–3c (after Brady).
- 1961 *Eponides lateralis* (Terquem) Braga : 155; pl. 16, figs 10, 11.
- 1961 *Poroeponides lateralis* (Terquem); Huang : 87; pl. 4, figs 29, 30.
- 1964a *Poroeponides lateralis* (Terquem); Rocha & Ubaldo : 415; pl. 2, fig. 11.
- 1965 *Eponides repandus* (Fichtel & Moll); Todd (*pars*) : 20; pl. 7, figs 4a–c only.
- 1970 *Poroeponides lateralis* (Terquem); Matoba : 58; pl. 8, figs 2a–c.

MATERIAL. 10 specimens. NB 9449, 9450.

VARIATION. Length 0.50–1.50 mm, breadth 0.37–1.12 mm, thickness 0.17–0.60 mm.

REMARKS. Our larger specimens have compressed later-formed chambers embracing the test for over half its circumference with areal pores covering the whole of their ventral surface. The umbilicus is open, sometimes with an umbilical flap.

There are too few well-preserved specimens in the Togoli material for us to follow up Resig's (1962) investigations into the status of the genus *Poroeponides* (see Remarks under *P. cribrorrepandus* Asano & Uchio, p. 100).

DISTRIBUTION. *Fossil*: Pliocene of Japan (Asano 1951d). The type specimens came from the Pliocene of the Island of Rhodes (Terquem 1878). *Recent*: Has been found in the western Pacific, East Africa, the Red Sea and the west coast of the Indian subcontinent.

***Poroeponides cribrorrepandus* Asano & Uchio**

Pl. 7, fig. 11

- 1951d *Poroeponides cribrorrepandus* Asano & Uchio in Asano : 18, figs 134, 135.
- 1954 *Poroeponides cribrorrepandus* Asano & Uchio; Cushman, Todd & Post : 360; pl. 89, fig. 24.
- 1955 *Poroeponides cribrorrepandus* Asano & Uchio; Takayanagi : pl. 2, figs 19a, b.
- 1959 *Poroeponides cribrorrepandus* Asano & Uchio; Graham & Militante : 96; pl. 14, figs 8a–c.
- 1963 *Poroeponides cribrorrepandus* Asano & Uchio; Matsunaga : pl. 47, figs 3a, b.
- 1964 *Poroeponides lateralis* (Terquem); Bhatia & Bhalla : pl. 2, figs 3a, b (*non Rosalina lateralis* Terquem, 1878).
- ? 1964a *Eponides repandus* (Fichtel & Moll); Rocha & Ubaldo : 414; pl. 2, figs 10a, b.
- 1964 *Poroeponides cribrorrepandus* Asano & Uchio; Le Roy : F39; pl. 9, figs 26, 27.
- ? 1964b *Poroeponides lateralis* (Terquem); Rocha & Ubaldo : 647 (list); pl. 1, figs 11, ? 15.
- 1965 *Eponides repandus* (Fichtel & Moll); Moura : 50; pl. 6, fig. 8 (*non Nautilus repandus* Fichtel & Moll, 1798).
- ? 1968 *Poroeponides lateralis* (Terquem); Bhalla : 387; pl. 2, figs 8a, b.
- 1970 *Poroeponides cribrorrepandus* Asano & Uchio; Kim : pl. 3, figs 2a, b.
- 1970 *Poroeponides lateralis* (Terquem); Bhalla : 160; pl. 21, figs 6a, b.
- 1970 *Poroeponides cribrorrepandus* Asano & Uchio; Matoba : 58; pl. 8, figs 1a–c.

MATERIAL. 9 specimens, NB 9449, 9450.

VARIATION. Length 0.25–0.77 mm, breadth 0.20–0.60 mm, thickness 0.12–0.37 mm.

REMARKS. The status of *Poroeponides* has been questioned by a number of authors, in particular Resig (1962) who studied the species *Eponides repandus* (Fichtel & Moll) from a Californian off-shore sample of Pleistocene age. She states that the early stages were found to be true *Eponides*, but the intermediate stage developed the characters of *Poroeponides cribrorrepandus* Asano & Uchio, while the final stages represented forms which have been described as *Sestranophora arnoldi* Loeblich & Tappan.

Loeblich & Tappan (1964: C684) nevertheless have retained all three genera. They argue that such ontogenetic stages are characteristic of many foraminiferal genera and that only adult stages can be used in classification. We have only the '*Poroeponides*-form' in the Togopi material and therefore cannot comment further.

DISTRIBUTION. *Fossil*: Pliocene of Japan (Asano & Uchio in Asano 1951d, Matsunaga 1963) and Okinawa (Le Roy 1964). *Recent*: Has been widely reported from the western Pacific, the coasts of India and south-eastern Africa.

Family AMPHISTEGINIDAE Cushman, 1927

Genus AMPHISTEGINA d'Orbigny, 1826

Type-species: *Amphistegina vulgaris* d'Orbigny, 1826.

Amphistegina cf. *lessonii* d'Orbigny

Pl. 8, fig. 1

cf. 1826 *Amphistegina lessonii* d'Orbigny: 304, no. 3 (modèle 98 and pl. 17, figs 1–4 probably refer to *A. quoyi* d'Orbigny; see Ellis & Messina 1940 *et seqq.*).

MATERIAL. 3 specimens. NB 9449, 9452.

VARIATION. Maximum diameter 1.10 mm, thickness up to 0.60 mm.

REMARKS. Imperfect preservation of our material allows no more than a tentative identification.

Amphistegina cf. *wanneriana* Fischer

Pl. 8, fig. 2

cf. 1927 *Amphistegina wanneriana* Fischer; Fischer: 170; pl. 217, figs 131a–c.

MATERIAL. 11 specimens. NB 9450, 9452.

VARIATION. Greatest diameter 0.80–1.70 mm, thickness 0.40–0.70 mm.

REMARKS. *A. wanneriana*, erected by Fischer (1921: 251) for the *Amphistegina* sp. nov. of Wanner (1910: 761), was not formally described or figured until 1927 (*op. cit.*).

Our specimens are generally poorly preserved and, therefore, cannot be identified with certainty. They do not have the coarse ornament shown by *A. radiata* (Fichtel & Moll) var. *papillosa* Said or by *A. lessonii* d'Orbigny var. *pulchra* Cushman & Todd.

RANGE. *A. wanneriana* has been recorded only from the Pliocene sediments of eastern Indonesia.

Family CIBICIDIDAE Cushman, 1927

Subfamily CIBICIDINAE Cushman, 1927

Genus CARIBEANELLA Bermúdez, 1952

Type-species: *Caribeanella polystoma* Bermúdez, 1952.

Caribeanaella ogiensis (Matsunaga)

Fig. 64; Pl. 7, fig. 16

1954 *Oinomikadoina ogiensis* Matsunaga : 163, text-figs 1–3.1955 *Oinomikadoina ogiensis* Matsunaga; Takayanagi : pl. 2, figs 20a, b.1963 *Oinomikadoina ogiensis* Matsunaga; Matsunaga : pl. 50, figs 5a–c.

MATERIAL. 20 specimens. NB 9448, 9449, 9450, 9452.

VARIATION. Maximum diameter 0.49–0.70 mm, thickness 0.15–0.27 mm. Number of chambers in final whorl 7–9.

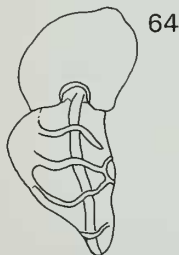


Fig. 64 *Caribeanaella ogiensis* (Matsunaga).
P50173. Apertural view of specimen figured on
Pl. 7, fig. 16. Sample NB 9450. $\times 65$.

REMARKS. Initially like *Cibicides*, this species develops on each of the later-formed chambers of the final whorl two types of supplementary apertures: one, a spiral slit at the inner margin, the other, a smaller aperture at the basal outer margin of the chamber periphery.

Our material agrees closely with the type figures. On the convex ventral surface the sutures are flush or depressed and often marked by a row of coarse pores. On the flattened spiral side the earlier whorls are obscured by thickening of the test; the final whorl has thickened sutures in the early part, narrower and depressed sutures in the later stage. Pores vary in size and distribution, sometimes being sparsely developed. We follow Loeblich & Tappan (1964 : C688–9) in regarding *Oinomikadoina* as a junior synonym of *Caribeanaella*.

There is no evidence that *Caribeanaella* in the Indo-Pacific is part of the growth cycle of *Planorbulina* as Schnitker (1969) claimed.

DISTRIBUTION. *Fossil*: Pliocene of Japan (Matsunaga 1954, 1963); Matsunaga (1954) also states that the species is found in the Pleistocene of Japan but does not figure the material. *Recent*: Japan (Takayanagi 1955).

Family PLANORBULINIDAE Schwager, 1877

Genus PLANORBULINELLA Cushman, 1927

Type-species: *Planorbulina larvata* Parker & Jones, 1865.*Planorbulinella larvata* (Parker & Jones)

Figs 65a, b, 66

1865 *Planorbulina larvata* Parker & Jones : 379, 380; pl. 19, figs 3a, b.1969 *Planorbulinella larvata* (Parker & Jones) Freudenthal : 82; pl. 4, figs 3, 4; pl. 5, figs 1, 2; pl. 6, fig. 4; pl. 12, figs 4–5b.

MATERIAL. 2 specimens. NB 9448, 9449.

VARIATION. Maximum diameter 0.86–1.36 mm, thickness 0.16–0.32 mm.

DISTRIBUTION. In his comments on the overall distribution of this species Freudenthal (1969) records it as commonly occurring in the Indian and Pacific Oceans (as far north as Japan) and in the Red Sea. There appear to be several reliable records as early as the Miocene (e.g. Le Roy 1964).

J. E. WHITTAKER & R. L. HODGKINSON
 Family ACERVULINIDAE Schultze, 1854
 Genus *GYPsINA* Carter, 1877

Type-species: *Polytrema planum* Carter, 1876.

Gypsina globula (Reuss)

Pl. 7, fig. 10

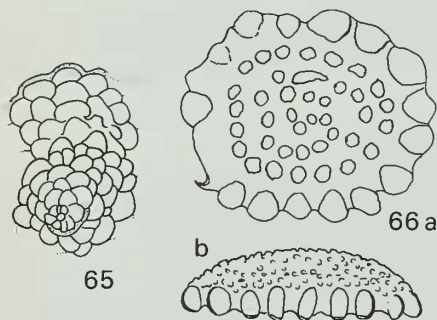
1847 *Ceripora globulus* Reuss : 33; pl. 5, figs 7a-c.

1884 *Gypsina globulus* (Reuss) Brady : 717; pl. 101, fig. 8.

MATERIAL. 5 specimens. NB 9450, 9452, 9460.

VARIATION. Greatest diameter 0.59-1.83 mm.

RANGE. Miocene (Reuss 1847, Le Roy 1964) to Recent.



Figs 65, 66a, b *Planorbulinella larvata* (Parker & Jones). 65, P50270. Segment of an equatorial half-section. Sample NB 9449. $\times 30$. 66a, b, P50269. Concave side and edge view. Sample NB 9448. $\times 40$.

Family CYMBALOPORIDAE Cushman, 1927

Genus *CYMBALOPORETTA* Cushman, 1928

Type-species: *Rosalina squamosa* d'Orbigny in de la Sagra, 1839.

Cymbaloporetta squamosa (d'Orbigny)

Pl. 7, fig. 13

1826 *Rotalia squamosa* d'Orbigny : 272 (106), no. 8 (*nomen nudum*).

1839 *Rosalina squamosa* d'Orbigny : 91; pl. 3, figs 12-14.

1839 *Rosalina poeyi* d'Orbigny : 92; pl. 3, figs 18-20.

1884 *Cymbalopora poeyi* (d'Orbigny) Brady : 636; pl. 102, figs 13a-c.

1915 *Cymbalopora poeyi* (d'Orbigny); Cushman : 24; pl. 10, figs 1a-c; pl. 14, figs 5a-c; text-figs 28a-c.

1921 *Cymbalopora poeyi* (d'Orbigny); Cushman : 308; pl. 59, figs 2a-c.

1949 *Cymbaloporetta squamosa* (d'Orbigny) Said : 40; pl. 4, figs 14a, b.

1954 *Cymbaloporetta squamosa* (d'Orbigny); Cushman, Todd & Post : 364; pl. 90, figs 15, 16.

1957 *Cymbaloporetta squamosa* (d'Orbigny); Todd : 292 (table); pl. 91, figs 10a-c.

1959 *Cymbaloporetta squamosa* (d'Orbigny); Graham & Militante : 108; pl. 18, figs 3a-c.

1960 *Cymbaloporetta squamosa* (d'Orbigny); Barker : 210; pl. 102, figs 13a-c (after Brady).

1961 *Cymbaloporetta squamosa* (d'Orbigny); Huang : 88; pl. 4, figs 14, 15.

1964 *Cymbaloporetta squamosa* (d'Orbigny); Rocha & Ubaldo : 144; pl. 17, figs 8, 9, 12.

1965 *Cymbaloporetta squamosa* (d'Orbigny); Todd : 38; pl. 20, figs 3a-c.

MATERIAL. 10 specimens. NB 9449, 9450, 9452.

VARIATION. Maximum diameter 0.52-0.60 mm, height 0.25-0.37 mm. Number of chambers in the last whorl 5-6.

DISTRIBUTION. *Fossil*: Sub-Recent of Timor (Rocha & Ubaldo 1964). *Recent*: Common in the western Pacific islands with an additional record from the Red Sea (Said 1949). First described from the Caribbean.

Cymbaloporetta bradyi (Cushman)

Pl. 7, figs 14, 15

- 1884 *Cymbalopora poeyi* (d'Orbigny) var.; Brady : 637; pl. 102, figs 14a-d.
 1915 *Cymbalopora poeyi* (d'Orbigny) var. *bradyi* Cushman : 25; pl. 10, figs 2a-c; pl. 14, figs 2a-c.
 1924 *Cymbalopora bradyi* Cushman; Cushman : 34; pl. 10, figs 2-4.
 1932 *Cymbaloporetta bradyi* (Cushman) Thalmann : 310.
 ? 1941 *Cymbaloporetta poeyi* (d'Orbigny); Le Roy : 42; pl. 3, figs 12-14.
 1949 *Cymbaloporetta bradyi* (Cushman); Said : 40; pl. 4, figs 14a, b.
 1954 *Cymbaloporetta bradyi* (Cushman); Cushman, Todd & Post : 364; pl. 90, figs 13, 14.
 1954 *Cymbaloporetta bradyi* (Cushman); Kleinpell : 68; pl. 9, figs 3a-c.
 1957 *Cymbaloporetta bradyi* (Cushman); Todd : 292 (table); pl. 91, figs 12a-c.
 1959 *Cymbaloporetta bradyi* (Cushman); Graham & Militante : 108, pl. 18, figs 2a-c.
 1960 *Cymbaloporetta bradyi* (Cushman); Barker : 210; pl. 102, figs 14a-d.
 ? 1961 *Cymbaloporetta bradyi* (Cushman); Huang : 88; pl. 4, fig. 21.
 1965 *Cymbaloporetta bradyi* (Cushman); Moura : 54; pl. 7, fig. 3.
 1965 *Cymbaloporetta bradyi* (Cushman); Todd : 37; pl. 19, figs 1a-4c; pl. 20, figs 4a-c.
 ? 1968 *Cymbaloporetta bradyi* (Cushman); Albani : 116; pl. 10, figs 15, 17-19.
 1969 *Cymbaloporetta bradyi* (Cushman); Resig : 57; pl. 7, figs 3a, b.
 1970 *Cymbaloporetta bradyi* (Cushman); Matoba : 50; pl. 8, figs 7a-c.

MATERIAL. 29 specimens. NB 9449, 9450.

VARIATION. Maximum diameter 0.40-1.2 mm, height up to 0.15 mm. Number of chambers in the last whorl 8-15. Up to eight whorls.

REMARKS. This species shows wide variation in the height of the spire, the number of chambers in the last whorl and in the general shape of the test, probably reflecting the mode of attachment. The umbilicus is usually open, but occasionally it is partially closed by extra shell material. Resig (1969) reports that the '*Tretomphalus*-stage' of the life-cycle has been observed in four of her specimens but no other authors appear to have recorded float-chambers in forms attributable to this species in the Indo-west Pacific region.

For further details of *C. bradyi* see Hofker (1951b : 477-484, text-figs 331a-e).

DISTRIBUTION. *Fossil*: Miocene/Pliocene of east Borneo (Le Roy 1941) and Fiji (Kleinpell 1954); Pleistocene of Hawaii (Resig 1969). *Recent*: Widely distributed in the western Pacific with additional records from the Red Sea and south-east Africa.

Cymbaloporetta plana (Cushman)

Pl. 4, figs 19a, b, 20

- 1924 *Tretomphalus bulloides* (d'Orbigny) var. *plana* Cushman : 36; pl. 10, fig. 8.
 1934 *Tretomphalus planus* Cushman; Cushman : 94; pl. 11, figs 11a-c; pl. 12, figs 18-22.
 ? 1954 *Tretomphalus planus* Cushman; Cushman, Todd & Post : 364; pl. 90, figs 17, 18.
 1971 *Tretomphalus bulloides* (d'Orbigny) '*planus* form' Todd : 166.

MATERIAL. '*Tretomphalus* forms' - 4; NB 9449. Specimens without float chamber - 86; NB 9449, 9450.

VARIATION.	' <i>Tretomphalus</i> forms'	Others
Maximum diameter	0.47-0.51 mm	0.29-0.65 mm
Height	0.40 mm	0.15-0.40 mm

Number of chambers in the last whorl 4-7, number of whorls 3-4.

REMARKS. Douglas & Sliter (1965) showed *Tretomphalus* is a junior synonym of *Rosalina*, the float chamber merely characterizing the gamont's planktonic stage. This reproductive phase, moreover, appears to be present in a number of species of *Rosalina* and *Cymbaloporetta*.

In the present material specimens with float chambers are rare, but on dissection are seen to be conspecific with the specimens without 'floats' found in the same sample. The species has the apertural characteristics of *Cymbaloporetta* and a flat or slightly depressed initial coil, and has

many fewer chambers than *C. bradyi* (Cushman). It compares most favourably with Cushman's original description of *T. bulloides* var. *plana* (1924: 36) which states 'the early chambers form a very much flattened cap and the whole "balloon-chamber" [when present] is much wider than high'.

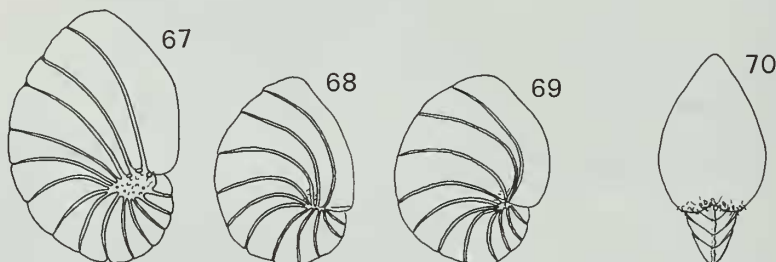
DISTRIBUTION. From the Recent of Samoa (Cushman 1924, 1934); Guam, Fiji and Pinaki Atoll (Cushman 1934) and possibly Eniwitok (Cushman, Todd & Post 1954). Todd (1971) reports, but does not figure, this form from Midway Atoll, also in the western Pacific. There is no previous fossil record.

Family **NONIONIDAE** Schultze, 1854

Subfamily **NONIONINAE** Schultze, 1854

Genus **FLORILUS**⁴ de Montfort, 1808

Type-species: *Florilus stellatus* de Montfort, 1808, nom. subst. pro *Nautilus asterizans* Fichtel & Moll, 1798.



Figs 67–70 *Florilus asanoi* nom. nov. 67–69, P50271–P50273. Side views showing variation in flaring of test. Sample NB 9450. 70, P50174. Apertural view of specimen figured on Pl. 7, fig. 17. Sample NB 9452. All approx. $\times 70$.

Florilus asanoi nom. nov.
(pro *Nonion japonicum* Asano, 1938)
Figs 67–70; Pl. 7, fig. 17

- 1933 *Nonion subturgidum* Cushman (*pars*): 43; pl. 10, figs 7a, b only (*non Nonionina subturgidum* Cushman, 1924).
- ? 1936a *Pseudononion tradecum* Asano : 622; pl. 33, figs 7a–c.
- 1938a *Nonion japonicum* Asano : 593; pl. 15, figs 1–2b.
- 1941a *Nonion boueanum* (d'Orbigny); Le Roy : 78; pl. 1, figs 13, 14 (*non Nonionina boueana* d'Orbigny, 1846).
- ? 1949 *Nonion nakosoense* Asano : 428, text-fig. 2, nos 14–17.
- ? 1950 *Nonion kidoharaense iwahorii* Fukuta : 151; pl. 1, figs 2a, b.
- 1950 *Nonion japonicum* Asano; Asano : 2, text-figs 5, 6.
- 1959 *Nonion japonicum* Asano; Graham & Militante : 71; pl. 11, fig. 1.
- 1963 *Nonion japonicum* Asano; Matsunaga : pl. 37, figs 3a, b.
- 1964 *Nonion japonicum* Asano; Le Roy : F27; pl. 10, figs 12, 13.
- 1966 *Florilus elongatus* (d'Orbigny); Belford : 158; pl. 31, figs 8–12 (*non Nonionina elongata* d'Orbigny, 1826).
- 1967 *Nonion japonicum* Asano; Konda : 34 (table); pl. 4, fig. 11.
- 1968 *Nonion japonicum* Asano; Chiji & Lopez : 108; pl. 15, fig. 6.
- 1969 *Nonion japonicum* Asano; Konda : 89 (table); pl. 8, fig. 4.

⁴ Since this paper went to press, Dr F. Rögl (personal communication) informs us that an application has been made to the International Commission for Zoological Nomenclature for the suppression of *Florilus*. Following the recent discovery of the Fichtel & Moll Collection in the Natural History Museum, Vienna, Rögl has found that the type-species of *Florilus* de Montfort is in reality a trochospiral form (i.e. a *Hanzawaia*), and therefore, to maintain stability of nomenclature, he considers the generic name should be suppressed, even though it has priority over *Hanzawaia*. If this application is ultimately upheld, the taxonomic position of *F. asanoi* will have to be reviewed.

MATERIAL. 196 specimens. NB 9449, 9450, 9452, 9456/7, 9460.

VARIATION. Length 0.27–0.52 mm, breadth 0.17–0.34 mm, thickness 0.14–0.22 mm. Number of chambers in the final whorl 11–16.

REMARKS. Both *Pseudononion japonicum* Asano, 1936 and *Nonion japonicum* Asano, 1938a, belong to the genus *Florilus*, and as they are distinct, the latter, which we consider to be conspecific with the present material, must be given a new name. A new name is also necessary if *Florilus* (interpreted by many authors as merely a flaring form of *Nonion*) is not considered to be a true genus. *Pseudononion*, its junior synonym, must then also be rejected, and there would be two species of *Nonion* with the specific name *japonicum*.

The shape of the test in the Togopi specimens is not constant (see Figs 67–69), the coil showing variation from moderately tight to strongly flaring. Nevertheless, the distinctive appearance of the final chamber, when seen in side view, is constant. The umbilicus is granular and the periphery of the shell, characteristically, non-lobate. In edge view the periphery at the beginning of the final whorl is acute to subrounded, and the apertural face variably compressed. *Pseudononion tradecum*, *Nonion kidoharaense iwahorii* and *N. nakosoense*, all from the Neogene of Japan, are very similar to variants in our material and it is possible that they may be conspecific with *Florilus asanoi*.

Florilus asanoi has occasionally been confused with two of d'Orbigny's species from the Tertiary of Europe, *Nonionina boueanum* and *N. elongatus*: *N. boueanum* possesses a markedly lobulate periphery, while *N. elongatus* has a final chamber which is narrow and strongly incurved at the umbilical end instead of broad and embracing as in *F. asanoi*.

DISTRIBUTION. *Fossil*: ? Miocene (Asano 1949, Fukuta 1950), Pliocene (Asano 1938a, Matsunaga 1963) and Pleistocene (Konda 1967, 1969) of Japan; Pliocene of Okinawa (Le Roy 1964) and New Guinea (Belford 1966). Late Tertiary (? Pliocene) of Siberia (Le Roy 1941a). *Recent*: The Philippines (Graham & Militante 1959), Japan (Chiji & Lopez 1968) and possibly Fiji (Cushman 1933).

Family **ANOMALINIDAE** Cushman, 1927
Subfamily **ANOMALININAE** Cushman, 1927
Genus **ANOMALINOIDES** Brotzen, 1942

Type-species: *Anomalina pinguis* Jennings, 1936.

Anomalinoides glabratus (Cushman)
Figs 71a–c

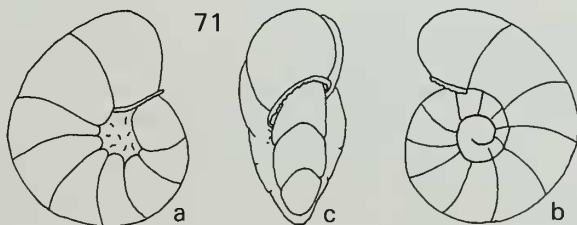
1924 *Anomalina glabrata* Cushman : 39; pl. 12, figs 5–7.

MATERIAL. 2 specimens. NB 9450.

VARIATION. Length 0.39–0.45 mm, width 0.33–0.34 mm, thickness 0.20 mm.

REMARKS. Placed within this genus on apertural characteristics.

RANGE. Miocene (Matsunaga 1963) to Recent.



Figs 71a–c *Anomalinoides glabratus* (Cushman). P50274. Ventral, dorsal and apertural views.
Sample NB 9450. $\times 70$.

Type-species: *Hanzawaia nipponica* Asano, 1944.

Hanzawaia nipponica Asano

Pl. 7, figs 18a, b

- 1944 *Hanzawaia nipponica* Asano : 99; pl. 4, figs 1–2b.
 1951c *Hanzawaia nipponica* Asano; Asano : 16, text-figs 24–26.
 1955 *Hanzawaia nipponica* Asano; Takayanagi : 45; pl. 2, figs 21a, b.
 1963 *Hanzawaia nipponica* Asano; Matsunaga : pl. 52, figs 5a–c.
 1964 *Hanzawaia nipponica* Asano; Ishiwada : pl. 8, figs 113a, b.
 1964 *Hanzawaia nipponica* Asano; Le Roy : F46; pl. 9, figs 28, 29.
 1967 *Hanzawaia nipponica* Asano; Matoba : 255; pl. 29, figs 14a–c.
 1968 *Hanzawaia nipponica* Asano; Chiji & Lopez : 107; pl. 15, figs 14a, b.
 1970 *Hanzawaia nipponica* Asano; Kim *et al.* : pl. ix-2, figs 5a–c.
 1970 *Hanzawaia nipponica* Asano; Matoba : 55; pl. 8, figs 10a–c.

MATERIAL. 11 specimens. NB 9450.

VARIATION. Length 0.33–0.40 mm, breadth 0.25–0.32 mm, thickness 0.10–0.11 mm.

REMARKS. The Togopi specimens are small for the species and only two show signs of supplementary lobe development, even though all possess clear chamber flaps on the ventral side. Topotypes (BM(NH) no. P45449) from the Kakio Formation of Japan, however, suggest that this feature can be quite variable.

DISTRIBUTION. *Fossil*: Miocene of Okinawa (Le Roy 1964); ? Upper Miocene/Pliocene (Matsunaga 1963), Pliocene (Asano 1944, 1951c) and Pleistocene (Matoba 1967) of Japan. *Recent*: Widespread around the coasts of Japan, but elsewhere it appears to have been found only off south-west Korea (Kim *et al.* 1970).

Postscript

Since this paper went to press, Ujiie (1977) has described and figured a number of species he previously listed (1970) from the M. Miocene Sandakan Formation of Sabah. Two of them are of particular reference to the present work as they are stated by us to be extinct and of possible biostratigraphical use (Fig. 3, p. 10).

The first of these, *Bolivina amygdalaeformis* of Ujiie (1977 : pl. 5, figs 3a, b), is a *Brizalina* and is referable to Asano's subspecies *Brizalina amygdalaeformis iokensis*, rather than to the nominate subspecies *B. a. amygdalaeformis* (Brady), which never has striations extending onto the last chamber (see p. 55). Ujiie's record is the earliest known occurrence.

The second, *Bolivina* cf. *tikutoensis* Nakamura (Ujiie 1977 : pl. 5, figs 7a, b), appears to be very close to or identical with our new taxon *B. sabahensis* (see p. 54), and thus extends its stratigraphical range down into the M. Miocene.

A further postscript is needed concerning the generic assignment of '*Schackoinella*' *globosa* (Millett), p. 63. Quilty (1975: 329) has recently redefined and refigured the poorly-known type-species of *Schackoinella*, *S. sarmatica* Weinhandl from the late Miocene of Austria, and has shown it to be a true glabratellid with an umbilical aperture and radially striate ventral side. Neither the aperture, difficult as it is to discern, nor the ventral appearance of Millett's species would now seem to allow its reference to *Schackoinella*, and therefore we propose to transfer it to *Murrayinella* Farias (1977: 343), a new genus tentatively assigned to the Rotaliidae. *Murrayinella*, type-species *Rotalia murrayi* Heron-Allen & Earland (1915), also includes *R. erinacea* Heron-Allen & Earland, as designated by Farias, which we have synonymized with *Murrayinella globosa* (Millett) (p. 63).

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